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EFORT CONGRESS VIENNA, AUSTRIA – 4 JUNE 2009

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Welcome to this first edition of the EFORT Comprehensive Review Course held in Vienna. This course is not intended to be exhaustive but should provide a firm basis for study. The concepts presented are up to date knowledge and the authors have provided many references. I would like to thank all the presenters and authors of chapters and I wish good and studious fun to the participants hoping that they will benefit from this collective effort.
Prof. Dr. Pierre Hoffmeyer, Chairman EFORT Scientifc Committee

The EBOT Examination
The European Board of Orthopaedics and Traumatology (EBOT) has developed a prestigious qualification in Orthopaedic surgery (Fellow / Member of the European Board of Orthopaedics and Traumatology) that has been gaining recognition from the scientific orthopaedic community throughout Europe since 2000. For the last 5 years we have been honoured by the recognition and sponsorship from the European Federation of Orthopaedics and Traumatology that has enable us to move into the next phase of the examination.
This new phase has very specific objectives aiming to improve the standards of orthopaedics training across the whole of the European Union and will take the examination into the new Internet era. Three main areas that have been selected to be developed over the next two years in order to optimize the outcomes of training, to decrease the differences that exist among trainees of the different training schemes and in order to help applicants to complete successfully this EBOT Examination.
EFORT is starting Comprehensive Review Courses designed to help applicants to be better prepared for the European Board Examination. The first one in Vienna will be a good opportunity for trainees and young specialists to test the new project and give us the feedback.
The second area that will start later this year is the Interim Orthopaedic Examination through the Internet for all trainees in Europe. This will for sure help not only residents to improve their skills before the final exam but will also be a valuable tool for the head of training in the different units to improve their expertise in teaching and training orthopaedics and traumatology for all residents.
The last area that has been selected is the exam itself. A new format for the written exam (also MCQ) has been approved. It will be taken separately from the oral exam and will be held on the same day in each EU Country through the Internet.
We do hope that all these changes will help to improve the standards of orthopaedic training in the EU and also help applicants to be better prepared for this prestigious European Qualification. I am sure that you will benefit a great deal and enjoy this first Comprehensive Review Course organized by EFORT.
Prof. Dr. Jorge Mineiro MD PhD, Chairman of the EBOT Examining Committee

The Federation of Orthopaedic Trainees Europe (FORTE) is a very young organization which wants to join all the trainees in Europe. The main goals are education, fellowships and networking for the trainees in Europe. You cab find a lot of information on our web-site:
www.forte-orthopaedics.com which is currently under reconstruction. We hope, as the board of the FORTE, that in Vienna a lot of trainees will join us!
Dirk-Jan Hofstee, Past president FORTE

INDEX

BASIC SCIENCE
Biomechanics of musculoskeletal tissues
Biomaterials (trauma, prosthetics)

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Biomechanics

The mechanics of systems, including the human body, is governed by Newton's Laws of Motion. The 1st Law states that "a particle will remain in a state of rest, or move at constant velocity, unless acted upon by a force". The 2nd Law states that "a particle acted upon by a force will change its velocity in proportion to the applied force". While the 3rd Law says that "when two bodies exert a force upon each other the force acts on the line connecting them and the two force vectors are equal and opposite". What do these laws mean when applied to the human body? Firstly for anything to start moving a force has to act on it, secondly how fast it moves depends on the magnitude of the applied force. The applications of these two laws to the human body are relatively obvious, muscles act by contracting and thus generating a force. What needs to be considered is that shortening a muscle against no resisting force requires no muscle force, what produces the force is the muscle shortening against some form of resistance. The third law is commonly restated as "every action has an equal and opposite reaction" and it is this law combined with the first law that is used in calculating forces occurring in the body.

The second basic element needing to be considered in biomechanics is the behaviour of levers. Archimedes (287-212BC) is quoted as having said "Give me a fulcrum and I will move the world". We can analyse the behaviour of the human body as a mechanical system by modelling the bones as levers, the weight of components of the body as the loads which need to be moved and the muscles as the applying forces. Levers come in three classes, depending on the relative positions of the fulcrum, the pivot point about which the lever moves, and the load force which the force which needs to be moved and the effort force which is the force doing the moving, that is the muscle force in the body. An example of a Class I lever is the child's seesaw, where the fulcrum is in the centre and the two people are the load and effort forces. In the human body there are few Class I levers, one example is at the head where the C1 vertebra acts as the fulcrum, mass of the head is the load force and is anterior to this fulcrum, while the extensor muscles of the neck supply the effort force. In Class II and III levers the fulcrum is at one end of the lever and the load and effort forces are to the same side of the fulcrum. In Class II the load force is between the fulcrum and the effort force while in Class III the effort force is between the load force and the fulcrum. As the forces multiplied by their distance from the fulcrum have to balance where the effort force is nearer the fulcrum than the load force the effort force has to be higher than the load force that is a Class III lever and this the most common type of lever found in the body.

Force is measured in Newtons (N) in the SI (Système International) unit scheme. 1 Newton is the force exerted by 1 kg (kilogram) when accelerated at 1ms-2, thus force exerted by 1kg on earth is 9.81N as the acceleration due to gravity on earth is 9.81ms-2. One simple way to remember the value of a Newton is that the force exerted on earth by a typical apple weighing about 100g is about 1N.

In calculating the biomechanics of the body we can start by considering a simple action, holding a weight in the hand with the forearm held horizontal and the upper arm horizontal. The weight is acting downwards and to be held still the upwards forces in the arm through to the body must be equal and the moments about the elbow joint must be equal. If we assume the weight of the lower arm is 20N and the weight held in the hand is 10N (thus approximately 2kg and 1 kg mass respectively) and that the length from the elbow joint to the hand is 300mm and the centre of mass of the forearm is 130mm from the elbow with the line of action of the biceps muscle being 50mm. We can then do the calculations to find that the force in the biceps has to be 112N.

If we apply similar calculations to a person standing on one leg and making appropriate assumptions of distances in the body then we can calculate that the load on the femoral head is 2.58 times the subject's body weight and that the forces in the abductor muscles is 1.77 times body weight. If these simple calculations are compared with the data of Bergmann et al using an instrumented hip prosthesis (Bergmann, Graichen et al. 1993) then it can be seen that the forces calculated using a simple two dimensional analysis can give a good estimate of the actual forces occurring in vivo.

The final factor to be considered is the number of load cycles applied during walking and other activities. (Wallbridge and Dowson 1982) found that the number of load cycles applied to the legs dropped from an average of 2 million per year when people were in their 20s down to 0.5 million in their 80s. The interesting factor was that they also measured some joint replacement patients and found they these people were applying more load cycles than the average for their age group. In the hand (Joyce and Unsworth 2000) estimated similar number of load cycles for the fingers but estimated that the loading the fingers considered of two groups, high movement with low loads interspersed with limited motion but high loads.

Biomaterials

"A biomaterial is a non viable material used in a medical device, intended to interact with biological systems" according to (Williams 1999) and to function successfully it needs to be biocompatible, that is it "has the ability to perform with an appropriate host response in a specific application" (Williams 1999). The behaviour of a material in the body depends on two factors: the effect the implant material has on the body and the effect the body has on the implant material. The reaction to an implanted material (and thus implant) can be divided into four types: Toxic, that is it kills cells in contact with or away from implant, Bioinert, that is produces no response by the body and which never truely occurs as there is always a response from the body, but for most bioinert materials the response is minimal. Bioactive, which is encourages an advantageous response from the body and this will depend on where the implant is placed in the body and thus the required bioactive response and finally Biodegradable where the implant breaks down in the body to non-toxic components which are excreted by the body. The effects the body has the implant can be defined as the response of the material to the internal environment of the body from the physiological environment, protein absorption, which is a particular problem with polymers, degradation when not required and corrosion, which particularly applies to metal implants.

When we are considering the mechanical properties of a material these are measured using stress, which is the force per unit area and strain which is a measure of the change in dimension and the ratio of these two is called Young's Modulus or stiffness. Further mechanical factors of consideration are the ultimate strength, that is how much force a material can take before it breaks, the ductility, the amount a material deforms before it breaks and toughness which is a measure of how fast a crack progresses through a material once fracture starts. When choosing a material for use in the body one of the considerations is the mechanical properties of the material compared to those of the body component being replaced. Cortical bone has Young's modulus of 7-25GPa, strength of 50-150MPa and a fracture toughness of 2-12 MN m-3/2, while cancellous bone has modulus of 0.1-1.0GPa and compressive strength of 1-10MPa (Currey 1998; Currey 2006). Cortical and cancellous bone are both brittle, but being able to react to their mechanical environment can be considered to be "smart" materials. Cancellous bone behaves as a typical foam, that is increasing the density (or decreasing the porosity) increases the stiffness and strength (Gibson and Ashby 1999). Ligaments and tendons have non-linear mechanical properties with the stiffness increasing as the load increases. Materials can be defined into four basic groups: metals, ceramics, polymers and composites. Metals are normally used as alloys, that is small or larger amounts of other atoms are added to tailor the properties. Metals are reasonably stiff, ductile, that is they deform before they fracture, they generally have good fatigue properties and can be plastically deformed, that is they can be bent into new shape and remain there as is used in the moulding of fracture fixation devices. The major metals used in orthopaedics are the stainless steels, the cobalt chrome alloys, titanium and its alloys. Stainless steel used in medical applications is usually 316 or 316L and consists of 18% chromium, 13% nickel, 2.5% molybdenum, and the rest is iron. The presence of the chromium leads to the alloy being "stainless" as a chromium oxide layer is produced on the surface, which does not easily oxidise further. Stainless steel has a Young's modulus of 210 GPa, is ductile, can be deformed (cold worked) and the fatigue properties are acceptable. Cobalt Chrome alloy consists of 27-30% chromium, 5-7% molybdenum with the rest cobalt. This formulation means that there is no nickel which is important for those patients who are nickel sensitive. Nickel sensitivity rates are variable within Europe and can reach over 20% in the Scandinavian population. Cobalt chrome has a Young's modulus of 230 GPa, a higher fatigue limit than Stainless Steel and has good wear properties. There are three major groups of titanium: commercially pure which is >99% titanium, Ti-6%Al-4%V which is therefore 90% titanium, 6% aluminium and 4% vanadium and finally the shape memory alloys which are approximately 50:50 titanium nickel, with the exact composition being used to control the temperature at which the shape memory effect occurs. Most titanium alloys have a lower Young's modulus of 106 GPa, the wear debris is black in body thus looks unsightly to the surgeon, but this wear debris is not known to produced significant extra problems compared to other wear debris which may be as present in the body but is not as obvious to the surgeon. Titanium is notch sensitive, that is any notches or other sharp corners lead to significant reductions in the fatigue life, and also is heat treatment sensitive. (Cook, Thongpreda et al. 1988) showed that with appropriate heat treatment the fatigue limit, that is the fatigue load at which the specimen does not break was 625MPa, but if a porous coating was applied with an inappropriate heat treatment this fatigue limit was reduced to 200MPa. More recently newer titanium alloys are being developed which have yet lower Young's modulus, at 42GPa, thus bringing its stiffness closer to that of cortical bone (Hao, Li et al. 2007).

Bioceramics can be divided into 2 major groups, the bioinert which are principally zirconia (ZrO_2) and alumina (Al_2O_3) and the bioactive mainly hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$) and tricalcium phosphate ($Ca_3(PO_4)_2$). The bioinert ceramics are principally used for articulating surfaces as either ceramic-on-polymer or ceramic-on-ceramic. Initially Al_2O_3 initially was preferred as ZrO_2 can be morphologically unstable but now PSZ (Partially Stabilised Zirconia) is available. Al_2O_3 has been used by Sedel in Paris for more than 30 years as ceramic-on-ceramic hip replacements (Nizard, Pourreyron et al. 2008). In the initial implants the individual grains in the ceramics components were large and failures occurred, now grain size is $3.4 \pm 0.8 \mu m$ and failures have reduced to >1:2000. However, need very close tolerances on head-cup dimensions are needed so matched pairs are supplied by the factory to reduce chances of fracture.

Bioactive ceramics are used in five major applications: bulk implants, that is space filling implants, porous when used as implants for ingrowth or scaffolds for tissue engineering, granules used to bulk out or to replace bone graft, coatings which are either plain HA or HA+TCP (also called biphasic CaP - BCP) and finally as injectable where the calcium phosphate, with or without some calcium sulphate, is mixed in the operating theatre, injected into the body and sets in situ.

Polymers used in orthopaedics are primarily ultrahigh molecular weight polyethylene (UHMWPE), polymethylmethacrylate (PMMA), other methacrylates, polyesters, poly(glycolic acid) and poly(lactic acid) and finally the hydrogels. Polyethylene was introduced by Sir John Charnley in 1960 as the first metal-on-polymer joint replacement. Charnely initially used polytetrafluoroethylene (PTFE) as the bearing surface for his hip replacements and found drastic wear such that after 1 year the motion was seriously reduced. He originally High Density Polyethylene (HDPE), which was replaced in 1970s with Ultra High Molecular Weight Polyethylene (UHMWPE) and now a range of Enhanced Polyethylene (partially cross linked) or heavily irradiated PE are used to reduce the production of wear particles. PE is used as concave bearing surfaces against metal or ceramics such as acetabular cups, the tibial plateaux of knee replacements, patella buttons etc. PMMA bone cement is used to fix (grout) joint replacements in place thus is used to space fill. It is supplied as a two phase materials, the powder phase is pre-polymerised polymethylmethacrylate beads plus benzoyl peroxide which initiates the polymerisation of the liquid monomer with a radiopacifier in the form of barium sulphate or zirconia. The liquid phase is methylmethacrylate monomer plus N,N dimethyl–p-toluidene. It is mixed in theatre when polymerisation starts due to the benzoyl peroxide producing free radicals that initiate the polymerisation of the MMA monomer. The rationale for the use of pre-polymerised beads and monomer is that the polymerisation process is exothermic, that is produces heat, and the monomer shrinks by approximately 21% during the polymerisation process. By using about ⅔rds pre-polymerised and ⅓ monomer the exotherm and skrinkage are both reduced. When in the "dough" state it is inserted into patient, under pressure and then implant pushed into the cement. Initially cement was hand mixed but now mixing is always performed under vacuum as this reduces the porosity (Wang, Franzen et al. 1993) thus improving the mechanical properties and reduces the exposure of theatre staff to the monomer fumes. Opacifiers are added to bone cement as being a polymer it is not visible on radiographs, but the opacifiers provide their own problems, acting as brittle fillers and thus reducing the mechanical properties and when the cement breaks up can become embedded in articulating joints increasing the wear in the joint and the presence of opacifier particles can lead to resorption of bone around the implant (Sabokbar, Fijikawa et al. 1997). Furthermore antibiotics can be added prophylatically to bone cement to reduce the risk of infection (Jiranek, Hanssen et al. 2006).

The degradable polymers used are Poly(lactic acid) PLA & Poly(glycolic acid) PGA. Chemically these break down to lactic and glycolic acid, which the body breaks down to CO_2 and H_2O and excretes. Typically PGA is used in degradable sutures as PGA has fast degradation within the body. Due to its lower degradation rate PLA is starting to be used for fracture fixation in low load bearing applications the form of internal fixation plates. The current problems with degradable polymers is the strength and degradation rate. In attempts to improve the strength fibre reinforcement and ceramics reinforcement has been used (Bleach, Nazhat et al. 2002; Huttunen, Törmälä et al. 2008).

Composites are two phase materials were the two phases can be seen as separate either with the naked eye or using a microscope, that is the two phases can be differentiated on the micron scale. Artificial composites are generally used to optimise the properties of the two phases. The individual phases interact be it mechanically or functionally. The major groups of composites are polymer reinforced with ceramics/glasses, polymers reinforced with different polymer or polymer form such as drawn fibres of a polymer in a amorphous matrix of the same polymer, an example is the PLLA in PLDLA used in some degradable fracture fixation plates. Ceramic metal composites, which are also known as metal matrix composites a few of these have been developed for medical applications and finally ceramic-ceramic composites, but neither of these but have as yet reached clinical applications. In a composite there is normally one continuous phase called the matrix and a second phase called the filler distributed in the matrix as particles, fibres or fabric. Generally phases chosen as when specific properties of one phase are "good" in the other they are "bad", but by getting right balance of phases can balance the properties to optimise the material. Applications of biocomposites in medical applications is beginning to increase (Tanner 2009). The earliest ones were bioinert, but now bioactive implants are beneficially interacting with the human body.

Conclusions

In conclusion when placing implants in the body there are two major interacting factors that need to be considered for the survival of an implant in the body. The first is how heavily is it being loaded and the second is what is it made of. Without appropriate interactions between both of these factors an implant will not be successful

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Diagnostic work up and recognition of primary bone tumours

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Whilst we know that the frequency of metastases of bone is unknown we know that bone sarcomas occur at approximately the rate of six cases per million, therefore in the United Kingdom we are likely to see 360 cases per annum. They present in a number of ways. The commonest is by pain, secondly by swelling which is more common in children, occasionally by pathological fracture and rarely by alteration of leg or arm alignment. It is a disease essentially of young people, although rare below the age of five years. Diagnosis is dependent upon consideration of the problem. Symptomatology of persistent pain or swelling should lead to an x-ray. X-ray should lead to recognition of a radiological abnormality. Review of the radiological abnormality would suggest:

1. What is the lesion doing to the bone?
2. What is the bone doing in response to the presence of the lesion?
3. Are there any characteristic features detectable?

Radiological consideration should be given to the age of the patient, the site of the lesion within the bone and the radiological appearance. Having established the consideration that a primary bone tumour may be present it is important to stage the patient locally and distally. Local staging essentially takes place by an MRI, distal staging takes place by CT scanning and Technetium Bone Scanning or occasionally by PET Scanning. Once the lesion is staged it is important to obtain a tissue diagnosis. Most commonly throughout the world this is performed by targeted (CT, plain radiographs or Ultrasound) Jamshedi needle biopsy. This method is 98% accurate in peripheral malignancies in centres of excellence. If pathological excellence is not available then open biopsy should probably be considered. It has long been understood that open biopsy leads to larger local contamination and clinical morbidity in the paper of Mankin dating back to 1982 shows that it worsens prognosis in 8% and therefore increases the risk of amputation. Once staging and biopsy are complete then the tumour is placed into Enikins' clinical staging system which is as pertinent today as when it was first described. In the late 1970s all malignant primary bone tumours apart from chondrosarcoma are given neo-adjuvant chemotherapy and then subjected to resection and reconstruction. It is beyond the scope of this lecture to discuss methods of reconstruction, but the use of endoprosthesis will be described briefly.

Diagnostic algorhythm and treatment options of bone metastases

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Oncology management is becoming an increasingly more serious task in orthopaedic and trauma surgery. A significant number of patients, who have solitary or multiple bone metastases can survive on cytostatic treatment for years.

The significance of the treatment of bone metastases is indicated by the fact that they are 80-100 times more common than primary malignant bone tumors. Various cancers have very different „bone affinities" as concerns their metastases. In 65-85% of bone metastases the primary site of the tumor is in the breast, lung, kidney and prostate.The bones most frequently involved in decreasing sequence are:lumbar, dorsal, cervical spine, ribs, proximal femur and tibia, skull, pelvis, sternum and humerus. Only 1-2% of these secondaries affect the short tubular bones of the hand and foot.

Symptoms: Deep intermittent pain that is independent of the movement, often presents weeks or month before the X-ray changes are detected. The case history (primary cancer!) and laboratory tests must be thoroughly evaluated. In 10-30% of cases the first episode is a pathologic fracture of a lytic metastasis of kidney or lung cancer.Osteoplastic metastases of prostate cancer rarely break and have good propensity to heal.

Imaging: In suspected cases, e.g.when there is local bone pain after history of tumor, an X-ray is taken of the area in question and CT, MR (occasionally PET-CT) scans are added if necessary. In spine, in the opposite of spondylitis the tumor involves single vertebral bodies, invading the intervertebral space only in later stage. In the long tubular bones, the lesion may be central, though it is more often eccentric, involving the cortex. Periosteal reaction is in most cases absent. Bone scan is also extremely important to decide if the process is single or multiple.

Prognostic factors: The most sensitive prognostic factor is the origin of the primary tumor. In cases of breast, prostate, thyroid and kidney cancers, the expected survival time is much longer than in cases of lung cancers or bone metastases of melanoma. The life expectancy is poor when the primary tumor is unknown or inoperable, or when the primary is discovered at the same time as the metastases, if the metastases are inoperable, multiple or multiorganic.

Surgical treatment: The surgical intervention can be palliative or curative.The aims of palliative surgical treatment are: to alleviate the pain, to prevent the imminent fracture, to osteosynthesize and strenghten the bone in case of pathologic fracture using the less invasive technique, to reconstruct the motion and mobility of the patient ensuring a better quality of life.There is a broad range of the possible surgical procedures for reconstruction of the defect, i.g. intramedullary nailing, plating, curetting the defect and filling up with bone cement or insertion of a tumor endoprosthesis. Intramedullary nailing is advantageous for it is stable weight-bearing, and even if the tumor progresses, loosening of the implant is not likely. In 10-20% of the cases a curative-type radical tumor excision is warranted using limb-saving surgery and reconstruction of the defect by modular tumor endoprosthesis or allograft.

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Paediatric traumatology: Specific fractures in children

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Specific fractures in children are particular by the biomechanics of child's bone, the presence of growth plate and epiphysis and the type of trauma.

Specific types of trauma in childhood

A. Obstetrical trauma
1. Clavicular fracture displaced/undisplaced
2. Lesion of the brachial plexus
3. Proximal humeral fracture (epiphysis not visible on the X-rays)
4. Cervical or upper thoracic fracture with or without neurological impairment
5. Proximal femoral fracture

B. For babies and small infants: Battered children syndrome
Specific fracture:
1. Corner fracture
2. Multiple asynchron fracture,
3. Fracture of the rips
4. Skull fracture.

C. Upper arm lesion due to fall : Infants without established balance fall often with upper arm reception causing
1. Wrist or
2. Elbow fracture.

D. Infants and young adolescents: Mainly pull out fractures at the ligaments insertion than ligamentar lesions
Epiphyseal fractures

The easiest classification is the Salter Harris Thompson classification. More complicated fractures classifications like Odgen or AO fracture are also described in the literature.

Salter Harris classification
- Salter I : epiphyseal line fracture and displacement without fracture of metaphysis or epiphysis.
- Salter II : epiphysis is intact, the fracture line goes partially through the epiphyseal line and through the metaphysis.
- Salter III : fracture through the epiphysis and through part of the epiphyseal line.
- Salter IV : fracture through the epiphysis and the metaphysis.
- Salter V : compression of the epiphyseal line without visible displacement.

The type II is the most frequent.
Every time that a fracture involves the epiphysis itself, perfect reduction is mandatory. Types IV and V are more prone to growth disturbances, long term follow up and good knowledge of bone growth mechanism are mandatory for the treatment of this type of fracture.

Peterson describes a fracture which involves the metaphysis with secondary fracture line directing to the epiphyseal line with classification of four categories of increasing involvement of the epiphyseal line.

Specific diaphysal and metaphysal fracture

- Greenstick fracture
- Torus fracture
- Plastic fracture
- Subperiosteal undisplaced fracture
- Metaphyseal Peterson type fracture

Specific Children Fractures by anatomical location

A. Fingers:
The most common lesions are crush fractures of distal phalanx with soft tissue injuries and proximal phalanx epiphyseal fracture. The index and small fingers are the more often involved.
Mallet finger with partial or total epiphyseal fracture.

B. Former arm:
Radial fracture and Galleazzi, distal ulna dislocation
Ulna fracture or incurvation with radial head dislocation (Monteggia) (four types depending of the direction of dislocation).

C. Elbow:
Condylar fracture, supracondylar fracture, elbow dislocation with or without epitrochlea pull out. Radial head fracture/dislocation

D. Acromioclavicular fracture:
During growth, the fracture line goes through the epiphyseal line, at the lateral end of the clavicul, coraco-clavicular ligaments remain attached to the periosteum. Open reduction is advised.

E. Hip:
Femoral neck fractures are associated (Delbet type are associated with femoral head or femoral neck of both necrosis depending of the trauma energy).

F. Knee:
Fracture of the tibial spine. Classification of Meyers-McKeever depending on the displacement.
Fracture of the tibial tuberosity.
Fracture of the patella., Sleeve fracture, osteochondral fracture and patella dislocation.

G. Ankle fractures:
Triplane fractures, Tillaux-Chaput fractures, McFarland fractures. Osteochondral fractures of the talus.
This is not an extensive description of fractures in the growing skeleton but it's mandatory to know :
- the possibility of pathologic fracture, bone fragility, bone tumour or lytic lesion.

Fracture can occur without radiological signs

Epiphyseal fracture in small children, undisplaced fracture.
There is a lot of anatomical and development variations in the growing skeleton, a radiological atlas must be consulted for every specific case.

The mechanic resistance of the periosteum, the speed of bone healing, remodelling due to remaining growth are three features that influence fracture treatment in children towards conservative treatment.
Surgical treatments are mainly indicated for largely displaced instable fractures and epiphyseal fractures, fractures in polytraumatized children or open fractures. Approaching to the end of growth, treatments applied to adults are also indicated.

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Flat foot deformity appearing during growth of the healthy child

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Flexible flat foot in growing child appears mostly because of greater elasticity of the soft tissue. The prevailing opinion is that in the majority of cases does not require nonoperative and operative treatment.

Flexible flat foot with Achilles tendon shortening causes heel valgus leading to arthritis and pain in adolescents and adults. Pain and shoes discomfort in older children is proper indication for surgical procedure.

Tarsal coalition - a congenital union occurs between tarsal bones producing rigid plano-valgus foot. Coalition may be osseus (synostosis), consists of cartilage (synchondrosis) or fibrous tissue (syndesmosis). These coalitions are the more significant clinically causing peroneal spastic flatfoot, restricted range of subtalar motion and pain. Computed tomography or magnetic resonance imaging is standard diagnostic tools in detection of these abnormalities. Treatment varies according to type of coalition, the age of patient, the severity of deformity and the degree of disability.

Accessory navicular bone located on the medial aspect of the foot produces a flattening of the medial arch. In the past it was thought to be associated with a flatfoot deformity. Current studies show no relationship.

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Current surgical treatment options for fractures of the thoracolumbar spine

Introduction

This review course presents the current status of knowledge and treatment options available for spinal fractures. Emphasis is made on recent less aggressive surgical techniques. Several references are given in this syllabus.
Several spine textbooks are available for spine care, including management of traumatic injuries(Frymoyer 1997; Vaccaro, Betz et al. 2003). For surgical techniques and implants, the AOSpine Manual volume 1 ("Principles and Techniques") and volume 2 ("Clinical Applications") is a valuable tool (Aebi, Arlet et al. 2007). More information can be found on the AO website: http://www.aofoundation.org

Classification of thoracolumbar fractures and decision making

A complete and clear summary of current and historical classifications of thoracolumbar fractures can be found in the landmark publication by Magerl et al. in 1994 (Magerl, Aebi et al. 1994). This AO classification is currently the most frequently used classification system in scientific publications. However for all-day practice, a few studies have now shown that interobserver reliability is quite low as soon as observers go past the first level of classification (types A, B or C) (Wood, Khanna et al. 2005).
Choice of treatment is not only based on radiological aspects of the fracture, but also on general health condition of patients. For the same type of fracture, decision regarding type and timing of treatment can differ whether the patient is for example polytraumatized with neurologic lesions or monotraumatized without neurologic deficit.
There are several well known radiological tools that have been in use since long to characterize the fracture morphology, like standard Xray views and CT scan. The AO classification is based on those types of exams(Magerl, Aebi et al. 1994). More recently, possible ligamentous lesions have come to a closer attention using MRI. Taking into account imagery improvements and the patients' neurological condition, a new classification system has been proposed by the Spine Trauma Study Group: The Thoracolumbar Injury Classification and Severity Score system or TLICS (Vaccaro, Lehman et al. 2005; Patel, Dailey et al. 2009).

Non-surgical treatment

At the beginning of the 20th century, before the advent of surgical treatments, fractures of the thoraco-lumbar spine were treated by bracing. Lorenz Böhler (1885-1973), an Austrian trauma surgeon, described reduction and bracing techniques for spinal fractures as well as deformities resulting from such fractures (Böhler 1929). Some of these bracing techniques are still used nowadays.
Depending on the amount of deformity and anatomical localization of the fracture, non surgical treatment can be prescribed: functional treatment without bracing, or bracing with or without external reduction manoeuvres. Modern manufacturing techniques allow us to apply light custom made polyethylene braces. Handmade braces under strict supervision of the treating surgeon can sometimes still be needed, especially when external reduction manoeuvres are needed.
Another important factor of non surgical treatment is muscular strengthening exercises while wearing the brace.
With the advent of modern less aggressive surgical techniques, we might be facing in the upcoming years a shift towards surgical treatment in lesions that would have been classically treated conservatively.

Initial management of spine fractures in polytrauma patients and spinal cord injury

Spinal fractures very often result from high energy trauma and affect a very young age class of the population. In fact, most of those lesions are due to motor vehicle accidents (MVA). Depending on the fracture morphology, the occurrence of neurological lesions varies in average between 20% and 55% (Magerl, Aebi et al. 1994). Initial management of polytrauma patients follows ATLS guidelines (ABCDE). A rigid collar should be applied at the scene of the accident to protect the cervical spine and the patient is carefully mobilized (log roll). First priority is given to lifesaving procedures, airway protection and cardiopulmonary resuscitation (ABC) that also have the benefit of protecting the spinal cord from secondary ischemic damages, then attention is driven towards neurologic function (D). Once vital functions have been stabilized, surgical management can be decided (Patel, DeLong et al. 2004; Harris and Sethi 2006).

Surgical treatment

If surgical treatment is seldom controversed in spinal fractures with neurologic injuries, there is currently no consensus on what should be done for patients without neurologic deficit (Wood, Buttermann et al. 2003; Wood, Bohn et al. 2005). In these cases, surgical indication is based on evaluation of stability using biomechanical principles, but also, we have to admit, on "local" philosophical viewpoints, depending on the surgeons' training.

Three criteria are generally applied for treatment decision: neurologic stability, mechanical stability and deformity (local and regional).

Neurologic stability is defined as protection of the spinal cord from any other damage. It is not the purpose of this review course to go too much into details of neurologic damage and how to prevent it from worsening, but some crucial points will be presented. Emergent decompression and stabilization is mostly recommended in partial or progressive neurologic deficit. It is also noteworthy to acknowledge that the use of corticosteroids should not be recommended anymore in the current management of spinal cord injuries due to the fact that there has been no clear scientific evidence of any benefit from this drug which can have serious adverse effects(Fehlings 2001; Hawryluk, Rowland et al. 2008; Rowland, Hawryluk et al. 2008).

Mechanical stability is defined as the ability of the spine to allow a physiologic range of motion while protecting the neural structures of the spinal canal(White and Panjabi 1990). Although it may seem as a simple and obvious definition in theory, in practice it is not such. When mechanical instability results in neurological instability, the decision process for treatment can be quite simple. When only mechanical instability is suspected based on trauma mechanism and radiological criteria, it can be more challenging. For that purpose, MRI has made its debut a few years ago to help assess possible ligamentous injuries, not or less well detectable on standard Xray views or CT scan(Lee, Kim et al. 2000).

Kyphotic deformity can be local (vertebral kyphosis) or regional, between upper and lower endplates of adjacent vertebrae (traumatic regional kyphosis). The cut-off amount of kyphosis between non-surgical and surgical treatment will vary depending on anatomical localization of the fracture. Typically, a regional kyphosis of max 15° is tolerated for fractures around T11 and L1. For fractures above, greater deformity angles are tolerated and for fractures below, smaller angles.

The safest and quickest option for emergent decompression and stabilization of a thoracolumbar fracture with neurologic deficit is a classic posterior midline approach. Posterior stabilization can be achieved using short segment fixation techniques or longer constructs, in porotic bones for example.

A second anterior approach for additional decompression and reconstruction, if needed, can be postponed until the patient's general condition is stabilized. The load-sharing classification system can be useful in deciding whether there's a need for an anterior vertebral body reconstruction or not(McCormack, Karaikovic et al. 1994).

For fractures without neurologic deficit, treatment approach is based on the evaluation of mechanical instability, amount of deformity (kyphosis), but also other factors such as age, level of activity or socio-economic aspects.

New trends in surgical treatment of thoracolumbar fractures

Trauma and spine surgeons have always been striving to offer the best possible treatment while reducing aggressiveness of surgery. Several technical and implant innovations have been made these last years and help the surgeon to reduce soft tissue damage.

Video assisted endoscopy is a valuable tool to perform corpectomies and anterior column reconstruction. Obviously, there still is a need for a minimal skin incision size to get the implants in place. Other techniques addressing the anterior column (vertebral body) are cementoplasties (vertebroplasties) or balloon kyphoplasties. These techniques have proven to be useful in osteoporotic fractures of patients of 60 years or older(Wardlaw, Cummings et al. 2009). However, the long term fate of synthetic cements like PMMA injected in the vertebral body is unknown, an issue in young active patients. Biologically active cements have also been proposed, but seem to be more friable. Those treatments are currently evaluated by ongoing clinical studies.

Less invasive posterior based techniques are now also available and can interestingly be used in osseous lesions (type A fractures and type B with predominantly bony lesions). They consist in percutaneous pedicle screw and rod placement. There is an obvious interest in applying these techniques in patients with high risk of perioperative cardiopulmonary complications.

More interestingly will be to asses the results of combinations of all these less invasive surgical techniques. To give an example, a fracture stabilization by posterior percutaneous pedicle screw fixation combined to percutaneous vertebral body fracture reduction and injection of a bioactive cement, such as it is already done nowadays in several trauma centers across Europe.

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Degenerative Conditions

The outer annulus in a normal disk is mostly type I collagen; the inner nucleus is type II collagen. With age, the ratio of keratin sulfate to chondroitin sulfate increases and water content decreases, leading to a cascade of secondary degenerative events (spondylosis), starting with disc height loss, and sometimes associated with disck herniation or calcification. These changes in turn can result in increased segment motion, compensatory osteophytes, buckling of ligamentum, and facet arthrosis, all of wich can cause neural impigment. The clinical presentation of spondylosis can be manifested as axial neck pain, radiculopathy and/or myelopathy in the cervical spine and low back pain, radicular pain or claudication in the lumbar area.

Cervical degenerative disease

The prevalence of degenerative cervical conditions is only less than of low back pain.Cervical nerve roots exist above their corresponding numbered pedicles. (C6 exists between C5 and C6.) Nonsurgical treatment should be attempted for the vast majority of patients with cervical radiculopathy. Many forms of nonsurgical treatment relieve the pain but may not alter the natural history of the disease.
Surgical management provides excellent and predictable outcomes in patients with progressive neurologic dysfunction or failure to improve despite time and nonsurgical treatment. Either an anterior or a posterior approach can be selected in the appropriate circumstances, understanding that neither is perfect and each carries its own set of pros and cons. Cervical myelopathy is typically a surgical disorder. Early treatment, before the onset of permanent cord injury, is recommended. An anterior approach is indicated in patients with myelopathy arising from one or two disk segments. Laminoplasty is indicated in patients with multilevel involvement (three or more disk spaces). A combined anterior-posterior approach is indicated in patients with multilevel stenosis and kyphosis, or those with postlaminectomy kyphosis. The surgical procedure chosen must be tailored to the patient's specific pattern of stenosis, comorbidities, and symptoms. Strict adherence to a blind algorithmic protocol should be avoided.

Lumbar degenerative disease

Up to 85% of patients will experience low back pain at some point their lifetime, and it usually resolves in a matter of weeks The mainstay for treatment of acute low back pain is nonsurgical. The vast majority (90%) of symptomatic LDHs improve with nonsurgical management. A paracentral disk herniation will affect the traversing nerve root, not the exiting nerve root. For example, an L4-5 left paracentral HNP will result in an L5 radiculopathy, not an L4 radiculopathy. An intraforaminal or extraforaminal HNP will affect the exiting root. The absolute indicators for surgical management of LDH are cauda equina and a progressive neurologic deficit. Both are rare. Lumbar spinal stenosis is typically associated with exertion. The differential diagnosis includes hip pathology, vascular disease, and peripheral neuropathy. The five main types of spondylolisthesis are degenerative, isthmic, traumatic, dysplastic, and iatrogenic. In situ posterolateral L5-S1 fusion is indicated for children and adolescents with a low-grade spondylolisthesis.

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A: Pelvic Ring

1- Emergency Management

High energy pelvic ring fractures are found in more than one third of all polytraumatized patients and are frequently associated with potentially lethal vascular, organic or soft parts lesions 1-3. Fractured bony surfaces as well as dilacerated veins cause retroperi-toneal low pressure bleeding in all cases. Life-saving, on site haemostatic prophylais can be implemented by the paramedics using pelvic belts or binders which provide tam-ponnade during transportation 4. Survival chances are optimized if victims are directly referred to a trauma center 5,6. If haemodynamic instability is present at admission, immediate and aggressive multidis-ciplinary team approach is required. Immediate laparotomy in an unsatble pelvic ring will annihilate the tamponnade effect and increase bleeding 7. External fixation using pelvic clamp or other systems should always be performed prior to other procedures such as retroperitoneal packing, laparotomy or angiographic embolization 8,9.

2- ORIF of the anterior pelvic ring

Less than one centimeter of stretching of the symphysis pubis is sufficient to cause a complete rupture of this joint. We therefore consider symphysis ORIF above this limit. ORIF is best achieved using reconstruction or anatomic plates located antero-superiorly. Anterior plates or double plates do not provide better stability and require unnecessary exposure. Simultaneous Repair of bladder or urethral tears with symphysis ORIF will prevent late fistulas or local infections and should be preferred if found in situ or documented on preoperative cystograms 10.

3- ORIF of the posterior pelvic ring

Persisting malunions are less tolerable at the posterior ring than anteriorly11, anatomic sacro-iliac realignment should therefore be the goal at this level. Fixation using less in-vasive approaches is preferred whenever possible. Percutaneous sacroiliac screw fixa-tion is optimal for sacro-iliac dislocations or minimally comminuted zone I-III sacrum fractures 12. Anterior plating of the SI joint allows for excellent control of the reduction, excellent stability while remaining less invasive. Although linked with higher risks of soft parts complications, fixation through a posterior approach must be considered in com-minuted sacrum fractures. Sacral bars do not provide sufficient vertical stability. Poste-rior plates bridging both iliac crests adds excellent stability to posterior constructs. However good the fixation, permanent neurologic sequelae are frequently associated with posterior pelvic ring dislocations 13.

4- Late sequelae, pelvic malunions and nonunions

Wether operative or nonoperative treatment is used, pelvic malunions or nonunions will occur in a number of cases 14. As a rule, we know that pelvic nonunions are much less tolerated than pelvic malunions. Surgical corrections in such situations require invasive, complex procedures and the goal must be to restore function more than radiographic cosmetics 15,16.

B: Acetabulum fractures

1- Imaging, classification & planning.

Judet-letournel remains the best classification tool for acetabulum fractures. Preopera-tive planning relies on a precise radiologic routine based upon AP pelvic films as well as CT. Since 3D reconstructions, can be produced by the surgeon himself using viewer applications available for free on the web 17. Oblique iliac and obturator views are no longer routine. ORIF is considered based on patient's condition, degree of displacement and joint congruency 18,19. Reposition of dislocated hip joints is always urgent. ORIF of acetabulum fractures should be performed after stabilization of the patient's condition and careful analysis of the fracture, ideally after 5-8 days. Urgent ORIF may be conside-red in unreductible dislocations, or if sciatic nerve palsy appears after reduction of the hip.

2- Choice of approach for ORIF
Most, if not all acetabulum fractures can be fixed through the three classical approa-ches. Posterior Kocher-Langenbeck for posterior wall fractures, transverse fractures as well as most type T fractures. Ilioinguinal for anterior column fractures, both column fractures or associ-ated anterior column fractures. Extended iliofemoral approach is res-tricted to delayed fixation or complex associated transverse fractures. Heterotopic bone risk is highest after extended iliofemoral approaches. The actual tendency is to perform most acetabulum ORIF through KL or ilioinguinal approaches. Modified Stoppa ap-proach is ideally suited for the reconstruction of anterior patterns extending through the anterior pelvic ring 20.

3- Results of ORIF
Even in the most experienced hands, up to 40 % of failures were reported after ORIF of fractures with posterior displacement. Posterior or associated posterior wall fractures. This fact must be always kept in mind whenever describing posterior wall fractures as „beginner's cases". Success rates of more than 80% are reported with anterior or both column fractures depending more upon the quality of reduction than any other criteria 21.

4- Geriatric fractures
Osteoporosis, poor general condition, comorbidities: all these may inrease the risk of failures after acetabulum ORIF and have often lead to a nonoperative option in geriatric patients. We must remember that nonoperative treatment of such unstable fractures will lead to a poor functional outcome in most cases.
Keeping in mind the problematic prognosis of posterior wall fractures, the current trend is to consider, if patient's condition allows, a primary Total Hip Replacement for fractu-res involving comminuted posterior wall fractures. Fractures involving the anterior co-lumn, most frequent in the geriatric population, or both column fractures, are accessible through the anterior approach and are candidates for a primary ORIF if the condition of the patient allows 22.

C: Proximal femur fractures

1- Epidemiology
The increasing geriatric population will lead to an increased number of proximal femoral fractures in the coming years 23,24. Today, these fractures account for approximatively 20% of the total surgical activity of a general orthopaedic department with a 50-50 dis-tribution between intracapsular versus extracapsular fractures.

2- Femoral neck fractures - Arthroplasty
In the geriatric population, internal fixation of displaced femoral neck fractures is asso-ciated with higher rates of early surgical revisions. Primary arthroplasty using monobloc, bipolar or joint-replacing implants will be selected according to the degree of activity of these pati-ents. Surgical approach will vary according to the surgeon's routine and expe-rience 25-27.

3- Femoral neck fractures - Internal fixation
Femoral neck fractures in young or active patients are indications for femoral neck in-ternal fixation. Use of canulated screws is the stan-dard technique in Pauwels I & II frac-ture types. Failure to choose a sliding hip screw in Pauwels type III fractures will lead to a high rate of nonunions. Intertrochanteric valgus osteotomy is the treatment of choice in femoral neck nonunions 28.

4- Intertrochanteric fractures - Internal fixation
The choice of implant lies here between the sliding hip screw and the intramedullary hip screw devices. For A1 and A2 fractures, both options are adequate. IM devices provide a good control of potential shortening while allowing for less invasive procedures. Revi-sion rate, length of stay, morbidity are however slightly lower with extramedullary sys-tems 29. In type A3 fractures (reverse pertrochanteric), as well as subtrochanteric frac-tures, IM nailing devices are superior 30-32.

5- Metastatic fractures

Bone metastases with impending or existing pathologic fractures are frequently located in the intertrochanteric or subtrochanteric area. Functional consequences of these le-sions is such that operative fixation is often required. Hybrid constructs using plates with intrame-dullary cement are not as biomechanically sound as intramedullary nails. The risk of pulmonary embolism linked to reaming and nailing an unbroken femur in these debilitated patients must be kept in mind 33,34.

6- Fatigue fractures under biphosphonates

A new type of subtrochanteric or midshaft femoral fatigue fracture recently appeared in some osteoporotic patients who received fracture prophylaxis using biphosphonates for several years. Lateral cortical thickening, transverse fracture line originating at this level and extending medially are caracteristics of this new entity 35-37.

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Internal fixation in femur, knee and tibia

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1. Femur diaphysis (AO 32)

1.1 General remarks: Golden standard treatment is still reamed intramedullary nailing (1), usually as emergency procedure in the first hours after injury. Damage control orthopedics (DCO) with initial external fixator in cases with severe polytrauma especially with severe head and/or chest injuries (2). Change to definitive nailing as soon as possible, from day 3-10 ideally. MIPO with traditional or locked plates in cases with contraindication for nailing as curved femur, occluded medullary canal after previous surgery, periprosthetic fractures and in cases with high risk of infection (late change form ex fix to definitive internal fixation).

1.2 Antegrade nailing: Proximal to midshaft fractures. Entry point depending on nail type. New generation nails with lateral entry over tip or even lateral of the tip of greater trochanter, theoretically decrease surgery related damage to pelvitrochanteric muscle insertion.

1.3 Retrograde nailing: Distal metadiaphyseal extraarticular and/or simple distal intraarticular fractures (articular split, no Hoffa component). Also indicated in bilateral femoral shaft fracture, floating knee, obese patient (difficult proximal approach), in case with ipsilateral acetabular fracture, periprosthetic fracture after knee prosthesis (if center is free). Approach minimal invasive transligamenteous or paraligamentous (patellar ligament). Entry point at most distal point of intracondylar notch, in central axis of femoral diaphysis. Problems: Anterior knee pain in > 25% of the cases, sometimes due to primary or secondary nail protrusion into knee joint with rapid destruction of patellar cartilage and consecutive femoropatellar osteoarthritis (3,4).

2. Distal femur (AO 33)

2.1 General remarks: Domaine of periarticular locking plates (anatomical preformed). Alternative: Retrograde nailing in extraarticular and/or simple intraarticular fractures (see above)(5).

2.2 Locked plating: Minimal invasive technique by percutaneous insertion of the plate form distal to proximal submuscular under lateral vastus muscle (6,7). Different approaches in relation to the fracture pattern: Extraarticular fracture - lateral extraarticular approach; simple intraarticular fracture - anterolateral articular approach; complex articular fracture - parapatellar lateral articular approach with dislocation of the patella under knee flexion for full access to all 4 quadrantes of distal femur (8). Reduction/fixation: Articular component with open anatomic reduction and stable screw fixation, metaphyseal component with closed reduction using indirect reduction maneuvres and bridging fixation. Bone grafting only in rare cases necessary, infection rate low, union rate high, but higher rate of malunion compared to older series with traditional open plating (6,7).

3 Proximal tibia (AO 41)

3.1 General remarks: Region with critical soft tissue envelop similar to the distal tibia and ankle (9,10). Treat soft tissue injuries first in high energy fractures with complex intraarticular (bicondylar) or dislocation-type fracture pattern, using a staged procedure with joint bridging ex fix, compartement pressure measurement with fasciotomy if required, CT-scan for detailed fracture analysis and definitive reconstruction after 5-10 days.

3.2 Intraarticular fractures: Simple unicondylar split/depression fractures are fixed with ORIF using mostly a lateral standard approach submenical, anatomic reduction and plate and/or screw fixation. Locking plate not necessary, but anatomical preshaped plate can be helpful. Actual trend is to use smaller plates and screws (3.5mm) with „rafting" technique. Bone grafting/substitute required in larger metaphyseal defects especially in multifragmentary joint involvement. Bicondylar fractures (AO C-type, Schatzker 5-6) need ORIF of articular surface by limited open approach lateral (and seldom medial) and stable screw fixation. The metadiaphyseal part is ideally bridged with a strong locking plate (LISS or LCP 4.5/5.0) inserted in a MIPO-technique through the same lateral approach (11, 12). Posteromedial shearing fractures often need additionally a separate posteromedial small antiglide/buttress plate.

3.3 Extraarticular metaphyseal fractures (13): New generation tibia nails, with the option of high proximal interlocking in the tibia head, allow stable intramedullary fixation even of high metaphseal fractures. Preliminary reduction and fixation (using a temporay ex fix, percutaneous reduction forceps or even a small plate) prior to nail insertion and precise entry point of the nail are crucial factors (14). Equal successful are laterally inserted locking plates. Problems still remain with non and malunions despite correct intervention (11), requiring secondary bone grafting with/without restabilisation and/or corrective osteotomy.

4. Tibia diaphysis (AO 42)

Domaine of intramedullary nailing, golden standard still reamed nailing („ream to fit", no excessive nailing!). After reaming, union rate is higher and healing time shorter. New generation nails with improved proximal and distal locking options now allow successful treatment of fractures extending close to (or into) the ankle or knee joint (see above). Borderline regions for nailing remain still the proximal or distal metadiaphyseal junction. Alternatively, plate fixation in a ORIF- or MIPO-technique is a good solution (15, 16). As in all MIPO-approaches, the reduction is crucial and must be, especially in simple fracture pattern, as precise as possible. Reduction tools and tricks are manifold, the learing curve therefore has to be considered!

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An overview concerning foot and ankle trauma can be divided in 3 topics: expectations from severe trauma, the missed injuries and the up-to-date surgical techniques.

1. **Expectations from severe trauma . [1, 2, 3, 4]**
   a. In general foot trauma rarely needs emergency treatment. Exceptions are open injuries, incarcerated soft tissues, manifest compartment syndrome of the foot, and neurovascular injury. At 10 years follow-up there are significantly worse results functionally in patients with below knee injuries in polytrauma. Only half as good in physical function, form physical, bodily pain, ability to wear shoes and social function as their control counter parts Specific matched injuries tend to have worse outcomes.
   b. Basic principles of management allow maximising function by aligning the foot under the tibia, keeping the foot flat to the floor, making the foot foot-shaped and stabilising the joints to keep that position. Managing the soft tissue threat remains mandatory but early amputation could be thought about according to unreconstructable neuro-vascular and skin damages. Compartment syndrome, proximal or distal must detected and treated.
   c. Early trauma treatment will avoid later soft tissue release. Early mobilisation (stable and rigid fixation) will avoid excessive stiffness, long term swelling and post trauma disease
   d. Production of balance from ankle to hind foot to forefoot is vital by restauring the Mid foot columns length, the alignments of the hind foot and the stability of the ankle ligaments.

2. **Missed injuries [5, 6]**

They are numerous even the "subcutaneous" position of most of the anatomic structures in foot and ankle. We have to maintain an high index of suspicion regarding a so-called ankle sprain *(fracture of the lateral process of the talus, recurrent dislocation of fibular tendons...)*, midfoot or medial sprains involving to flat foot(Lisfranc dislocation), soft trauma at the foot leading to a complete dislocation revealing a Charcot foot ....

3. **New surgical procedures**
   a. Minimal invasive surgery (MIS) is proposed in various situations as such as LODA(arthroscopic assistance), Achilles rupture, Lisfranc dislocation, malleolar fracture, calcaneus fracture.[7, 8,9, 10]
   b. Navigation could be proposed to improve the accuracy of correction using post traumatic arthrodeses in ankle, mid or hind foot. [10, 11]
   c. New implants have been developed in term of design(adapted to the foot and ankle)(plate, screw,pin,anchor....) but also in term of materials (Titanium alloy), even using bioabsorbable components for scew, pin or plate.[12, 13, 14]

All those up-to-date techniques require further investigations at a long term follow-up to confirm the interest of their use.

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Adult hip and knee reconstruction: General aspects

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Introduction

Total hip and knee replacement are among the most successful elective surgical approaches being introduced within orthopaedic surgery. Developed in the 1960'ies and 1970'ies, respectively – both types of replacement have been through a detailed evolution, today used in several designs world-wide.

Across Europe, still more hips are being replaced per year than knees. However, the incidence are getting close to each other every year (average 170 total hip replacements (THR) per year per 100.000 inhabitants; and average 140 total knee replacements (TKR) per year per 100.000 inhabitants) (1, 2).

Cemented versus non-cemented design

Both THA and TKR were introduced as total cemented designs, but both have also been through the era of fully non-cemented designs – over hybrid designs – back to the total cemented implants. Today, still most THA and THR are total cemented implants (1, 2). During the last two decades, mainly Sweden has analysed and focused detailed on technique and quality of cementing technique (3). Hereby, survival of the implants has been significantly improved (3). However, in THR it is a general trend that younger patients are operated with non-cemented designs – the elderly by cemented or hybrid designs (1, 3, 4). In TKR, majority of operations are performed as total cemented (2).

Deep venous thrombosis

Deep venous thrombosis (DVT) and deep infection (DI) are serious complications after both THR and TKR. Therefore, prophylaxis against DVT both prior to and / or during surgery are mandatory across Europe.

DVT are published with an incidence as high as 30% after both THR and TKR if no prophylaxis is given (5). However, even after modern prophylactic treatment with low molecular weight heparin products – up to 13% has been published to develop DVT – most of these asymptomatic (6) The emphasize the real reason for DVT prophylaxis – to prevent the serious pulmonary embolism (5). Today, new products have been introduced to the marked, enabling per oral treatment to take over the former daily subcutaneous injections. It is however still debated what postoperative prophylaxis should be given to THR and TKR patients mobilized on the day of surgery and being described 2-3 days after the operation.

Deep Infection

DI after total joint replacement can ultimately result in amputation of the replaced limb. Although being very rare, such necessary final treatment is still shown. Besides, DI has a dramatic negative impact on sickness of the patient, mobility and the overall survival of the implant. It was shown already in the 1960'ies that preoperative prophylaxis with antibiotics reduced the incidence from round 4-5% to less than 1%. Today, prophylaxis with antibiotics is mandatory prior to both THR and TKR (2, 4), resulting in less than 0.5% of replacement being infected. Most frequently found bacteria in DI is Staphyloccus Aureaus, sensible for broader antibiotics like Dicloxacillen and second generation Cephalosporins.

Treatment of the early infected THR and TKR is recognised to involve a detailed debridement of the soft tissue, exchanging removable modular components and longer-term intravenous antibiotics (7). This strategy can be used within the first 6-8 weeks after the index operation. DI occurring later than 8 weeks and recurrent DI, are in general both in THR and TKR treated with removal of the implant, meticulous debridement of the soft-tissue, a period without a prosthesis and intravenous antibiotics – pronounced two-stage revision technique (8). By using such a strategy – and depending on the bacteria involved, the success rate is published to be approximately 70% in THR and 50% in TKR (8). Re-infection after two-stage treatment of primary DI are in high risk for ending as Girdlestone status in THR and knee fusion in TKR (8).

Survival of THR and TKR

Survival of THR are reported in the National Arthroplasty Registers to be approximately 92% after 10 years (1, 3, 4). Main reasons for revision are aseptic loosening, instability/dislocation and deep infection. Survival of TKR are in the register found slightly higher after 10 years (94%) with aseptic loosening of the tibial component and deep infection being dominating reasons (2).

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Hip reconstruction – osteotomy and joint replacement

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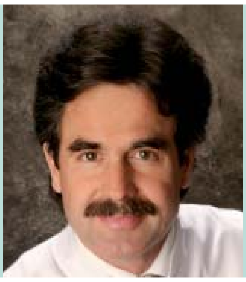

Several disorders of the growing hip (i.e. developmental dysplasia-DDH, tilt deformity with consecutive impingement, perthes disease) and avascular necrosis in the adult age are relevant mechanical risk factors for the development of hip osteoarthritis. In early disease stages with only minor morphological signs of cartilage degeneration osteotomies can help to preserve the joint. Indications are mild pain, absence of advanced radiographic osteoarthritis and an understanding of the procedure by the surgeon as well as the patient.

In adult patients with dysplastic hips pelvic osteotomies are more often performed than femoral osteotomies, as their reorientative potential is higher and they have less disadvantages. Common techniques are the Toennis "Triple osteotomy" and the Ganz "Bernese periacetabular osteotomy". Both have a significant potential to correct a pathologic acatabular coverage, although potential complications are associated with these major surgical procedures (i.e. risk of neurovascular damage, non-union and under-/over-coverage).
In avascular necrosis of the femoral head (AVN) femoral osteotomies are a treatment option in limited disease stages (ARCO II-III) with minor defect size (Kerboul-angle lower than 200°). In advanced stages or larger defect sizes the outcome is not encouraging. The Sugioka "rotational osteotomy" is rarely performed and technically very demanding.
In patients with a "tilt deformity" due to growth disorders or mild and often unrecognized slipped capital femoral epiphysis (SCFE) symptomatic femoroacetabular impingement might result. Surgical treatment options with dislocation of the femoral head through trochanteric osteotomy and open offset reconstruction have been developed.

In patients with advanced hip osteoarthritis joint preserving osteotomies generally are not any more indicated. If conservative treatment options over sufficient time periods (at least 3 to 6 months) fail and patient complain of significant pain and/or functional impairment, total joiunt replacement might be indicated.
Different options regarding choice of implant and fixation technique (i.e. "conventional" cemented, cementless, hybrid, hemiarthroplasty, surface replacement, neck preserving stems) as well as bearing materials (UHWM-polyethylene, highly-crosslinked polyethylene, metal-on-metal, ceramic-on ceramic) are available. Generally there is a tendency to recommend cementless prosthesis with hard bearings in younger and active patients, while cemented implants and conventional bearings are indicated in elderly and less active patients. All options, however, have their advantages and also disadvantages in special situations. Therefore general recommendations regarding the application of certain techniques or materials in any case are not possible.
Surgical exposure is possible via anterior, lateral, posterolateral as well as medial approaches and "minimally invasive" procedures have recently been developed. There is not enough evidence until now, however, to recommend these techniques generally.
Although THR is one of the most effective medical procedures, patients and surgeons must be aware of potential complications. Therefore, certain general steps should be done in every hip replacement surgery, which include
- controlled/safe patient positioning and check of correct side
- adequate soft tissue management (including repeated irrigation to prevent heterotopic bone formation)
- intraoperative control of leg legth and offset with trial prosthesis
- intra- and or postoperative x-ray control
- adequate treatment to prevent periprosthetic infection (single-shot antibiotics) and thrombosis (pharmaceutical and non-pharmaceutical options)
- immediate postoperative control of neuro-vascular status of the operated leg

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Adult hip and knee reconstruction: Osteotomy and joint replacement

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Summery

Several treatment options for the osteoarthritis of the knee in the middle-aged patients to preserve the joint are available. Osteotomies around the knee are well known and different procedures have been reported over years. However, not all results have been described as good. The most important factors for a successful result are preoperative planning, proper patient selection and a reproducible surgical technique with modern angle stable implants. The deformity to be corrected should be analyzed on a standing, three-joint radiograph, the choice of the side of the osteotomy should consider the joint line. The open wedge osteotomy at the tibia has several advantages compared to the closed wedge osteotomy. Greater corrections should be done by a double level osteotomy to keep the joint line horizontal. Base for successful modern surgical cartilage repair procedures in the knee joint is a stable joint with a normal limb. A necessary additional osteotomy around the knee should always to be considered.

Total knee replacement is a very successful procedure. Excellent long-term results have been reported. However, not all patients are satisfied with the prosthesis. Early revisions within two years after the implantation have been described. Correct alignment, rotation, balancing and fixation are the base of a excellent result. One of the most important issues for success are the soft tissue release techniques. The measured resection technique and the flexion gap balanced technique are the two current philosophies of implantation. The epicondylar line is accepted as the center of rotation for the femoral component. Replacement of the patellar or not, posterior stabilized or cruciate retaining prosthesis, cementing or not are the old controversies in total knee replacement. Navigation, minimally invasive techniques, mobile or fixed inlays, new materials (trabecular metal, highly crosslinked polyethylene), gender implants, high flexion design are the modern controversies. A proper surgical technique is still the most important factor for a good clinical outcome and to prevent early revision.

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Foot and Ankle surgery greatly improved in the last twenty years, improvements dues to better knowledge of physiopathology leading to more sound surgical techniques, improvements in anaesthetic techniques with reduction of pain, adaptation of postoperative cares and better understanding of reasons leading to failure, thus reducing recurrence and complications rates, and improving surgical results. This was accompanied by a huge development of orthotic, surgical devices and implants.

Anatomy

The surgical anatomy of the Foot and Ankle is all about making access to the major structures without damaging structures in the surgical field. The surface anatomy is therefore vital to planning surgical approaches. The major superficial nerves are the first vital set of structures to avoid in the planning of surgical approach. These include moving from the posterior lateral side round to medially and from proximal to distal, the sural nerve, the superficial peroneal nerve, the deep peroneal nerve which becomes more superficial distally, the saphenous nerve, the dorsal proper nerve of the great toe, the terminal branches of the tibial nerve including medial and lateral calcaneal nerves and the digital nerves to the toes. Once surgical incisions are planned taking this into account further thought in certain areas needs to be given to the blood supply and terminal arteries serving skin. Incisions need to recognise the exact position of joints in relationship to the skin and general shape of the foot. Particularly coming down the medial column it is surprisingly easy to place incisions distally and access the wrong joint. As the incision deepens the major neurovascular bundles become a hazard and as do the distal insertions of tendons.

Biomechanics

Practical biomechanics of the foot needs to recognise how the foot is maintained in a stable state during the act of standing in load bearing and propulsion. Normal gait is divided into stance (= approx 60%) and swing. The foot acts as an energy store and a stabiliser such that in midstance the foot is maximally stable and at its flattest position this is dictated by the major ligamentous structures especially the plantar fascia, the forefoot is held stably on the floor throughout stance once the foot flat position is obtained. This is effectively guaranteed by the reverse windlass mechanism the energy stored helps to put the foot into a propulsive mode as the body weight passes forwards and the heel rises. The windlass mechanism maintains the forefoot position while also continuing to tension the plantar fascia and in doing so the longitudinal arch of the foot raises and the heel goes into varus maximising the drive by an essentially passive mechanism. The role of the long tendons is essentially to balance the foot from side to side and cope with varying forces. In pathological situations the ability to maintain and balance the stability of the fore foot during stance is lost those intact tendons that resist increased deformity will fail, further deformity will be worsened by this and an increasing cascade of failure will occur.

History

Patients with foot pathology will usually complain of pain, loss of function and increasing deformity to varying degrees. Like in other musculoskeletal sites the presence of unremitting pain must be regarded as a red flag to the presence of significant pathology. The site nature and radiation of pain can often help identify the structures involved. The onset and the relationship to specific events can be similarly helpful. Associated symptoms such as tingling numbness and instability should be sort. Pre-existent deformity, disease and family history are all of relevance.

Examination

Examination of the foot needs to be systematised and thorough. A great deal can be learnt about the problem by observing the patient standing walking and by functional tests while standing before the patient is even touched. It is important to assess passive and active movements, motor function and neurology and particularly how these affect the balance of the foot.

Imaging

Imaging of Foot & Ankle pathologies includes: standard radiographs, US, MRI, bone scan, CT – arthrography, and Spect-CT. Standard radiographs are cheap, fast to perform, panoramic, ready available, but allow only a limited evaluation of soft tissue and do not assess bone marrow. US is a very powerful tool for tendons examination, can detect joint effusion, assess synovial hypertrophy and eventually guide a needle puncture. It can detect changes in nerve appearance and a compressive tumor in the tarsal tunnel. Teno-CT is the examination of choice if a longitudinal split or tear of one peroneal or of the tibialis posterior tendon is suspected. Spiral CT-arthrography is the best imaging technique to evaluate ankle cartilages. MRI is the best modality to evaluate ankle joints because of its panoramic, multiplanar capabilities and because of its high tissue contrast. IV Gadolinium helps in the demonstration of synovial hypertrophy. Spect-CT is a relatively new and very promising technique, combining the advantages of both bone scan and Ct-scanner.

Conservative treatment

In many cases of foot pathology, conservative treatment may be the best solution and includes painkillers, steroid local injection, immobilisation, physical therapy, muscle stretching, pads, correction of shoeing, orthotic and custom made shoes or boots. Careful examination of the patient will establish the type of pathology and lead to an appropriate treatment. In case of unsatisfactory result, surgery can be advocated.

Ankle

Surgery for ankle arthritis includes: 1. Cheilectomy either arthroscopic or open, 2. Periarticular osteotomies, 3. Arthrodesis either arthroscopic or open, 4) Total Ankle Replacement (TAR). Despite of all warnings against it, ankle arthroplasty, in comparison to ankle arthrodesis, is probably the treatment of choice in many advanced ankle arthritis, but surely not for all. Three components TAR, with mobile polyethylene spacer, are the standard in Europe. Indications are: good bone stock, adequate vascular status, no immuno-suppression, good alignment of hindfoot, maintained ankle motion, sufficient medial and lateral ankle stability, contra-lateral ankle arthrodesis, low level of sports activity (bicycle, swimming, walking, golf). Relative contra-indications are: severe osteoporosis, history of osteomyelitis or septic arthritis, segmental bone defect, smoking. Absolute contra-indications are: extended AVN, neuroarthropathy (Charcot), important misalignment, massive joint laxity (Marfan), highly compromised peri-articular soft tissues, neurological impairment and high level of sports activity.

Etiology of osteochondral lesions or defects (OCD) of the talar dome remains debated and their treatment is still improving. It is staged according to the extent and severity of OCD, with best results being obtained with either arthroscopic debridement and micro-fracture, or open autologous osteochondral transplant (mosaicplasty), or autologous chondrocyte culture and transplantation. Osteochondral allografts or synthetic materials are promising techniques, to be analyzed.

Chronic ankle sprains may lead to ankle instability, lateral, medial or rotational, whose treatment is surgical. Ankle sprains may also be the cause of peroneal tendons longitudinal tears, more rare complete ruptures, and tendons dislocation. All these lesions are often missed and require surgical repair.

Subtalar and Chopart

Arthrodesis of these joints remains the treatment of choice in case of advanced posttraumatic or idiopathic subtalar arthrosis, tarsal coalition and severe varus or valgus deformity of the hindfoot. Hindfoot should be placed in slight 5 degrees valgus and position secured with staples, k-wires, or, best, with screws. Post-operative regimen usually includes a casting period of 8 weeks.

Flatfoot

The adult acquired flatfoot is a progressive symptomatic collapse of the medial longitudinal arch of the foot. The term "acquired" implies that some structural changes cause the deformity in a foot that was structurally normal. The possible etiologies are: biomechanical disorders, neuromuscular imbalance, tendons impairment (posterior tibial tendon - PTT), a Charcot foot (neuro-arthropathy), post-traumatic sequels, degenerative arthrosis and inflammatory arthritis. Strong correlated factors are age, female patient, obesity and diabetes. The forces exceeding the static and dynamic restraints of the foot create progressive medial structures degenerative dysfunction (PTT - spring and deltoid ligaments) with progressive subluxation at subtalar and midtarsal joints.

Chronic stress cause PTT dysfunction and a hypovascular zone makes the tendon prone to degeneration. Stage 1: tenosynovitis\tendinosis - normal tendon length. Stage 2: tendon elongation – flexible hindfoot valgus. Stage 3: tendon elongation or disruption - fixed hindfoot valgus. Stage 4: rigid hindfoot with ankle involvement. Clinical signs include the "Single heel rise" test with poor or absent evidence of heel varus at heel rise and the "Too many toes" sign.

Conservative treatment is preferred as initial protocol. Stabilization and control of affected joints with orthotic can provide the patient a decreased level of pain and an increased level of function. The orthotic design should be acceptable to the patient's lifestyle to ensure compliancy. In case of symptomatic patients not controlled by conservative treatment or in case of clear progression of the pathology, surgical treatment should be advocated. Depending of the stage and severity of the deformity, most frequently bone and soft tissues procedures are associated, with tendon repair and transfer, tendon (Achilles) lengthening and ligaments (spring, deltoid) repair, calcaneal osteotomies and, finally, arthrodesis.

Achilles tendon

Achilles tendon acute ruptures are due to chronic degeneration of the tendon, with failure of the inhibitory mechanism of the musculotendinous unit, and risk is increased by corticosteroids (local or systemic) or previous treatment with fluoroquinolone antibiotics and derivatives. Treatments options include: A. Non-operative and B. Operative – Percutaneous, Mini-invasive or Open. Non operative treatment is an adequate option but treatment is complex. Best option is the surgical mini-invasive suture for standard cases with functional post-operative care. This solution combines the advantage of both classical open and conservative modalities, without their complications.

Classification of Chronic Achilles tendinopathies includes (Marks): I. Peritendinitis, II. Pantendinitis (peritendinitis and tendinosis), III. Tendinosis, IV. Insertional (subcategories frequently coexist). After failure of conservative measures, surgical treatment can be considered and includes various techniques: Brisement, Percutaneous longitudinal tenotomy, Open debridement, Excision and repair with FHL transfer and V-Y plasty.

Heel Pain – Tarsal tunnel

The heel pain syndrome is a poorly defined entity with numerous etiologies; some of them are very rare while others are extremely frequent. This paper presents some frequent etiologies as well as the proposed treatments. We will concentrate on the two main etiologies: plantar fasciitis and entrapment of the first branch of the lateral plantar nerve. Treatment is first always conservative and carries out good results in 80 to 90% of the patients. It must however be stressed that the healing process can take a long time and both the patient and his treating physician must be aware of that. Several therapeutic modalities are necessary. Actually, surgery is necessary in some 5 to 10% of the patients, all etiologies considered. If the diagnostic is carefully established, the surgical release gives favorable results in 90% of the entrapment neuropathies and recalcitrant plantar fasciitis.

Sinus tarsi syndrome

Sinus tarsi syndrome was described by O'Connor in 1958 in the case of old ligament trauma of the ankle; it was characterized by pain on the lateral aspect of the posterior tarsus when walking on uneven ground. The pressure of the lateral aspect of the sinus tarsi provokes an important pain. The patient describes a subjective instability of the hindfoot. The examination is normal. Standard and stress X-Rays are normal. Many studies described an important quantity of mechanoreceptors (Paccini corpuscules, Golgi and Ruffini receptors, and nervous fibers) in the sinus tarsi. Electromyocinesiology studies showed dysfunction of the peroneal muscles. The normal pattern of the peronei activity is obtained after injection of local anesthetic in the sinus tarsi. Subtalar arthrography showed disappearance of the micro-recessi normally seen along of the interosseus ligament.

The treatment was conservative or surgical. Conservative therapy consists in injection of anesthetic and cortisone in the sinus tarsi, along with proprioceptive reeducation. Surgery performs curettage of the sinus tarsi. Success of both conservative and surgical treatment was uncertain. Since use of Ct-scan and MRI, many pathologies have been discovered, such as osteochondral lesions, arthritis, congenital tarsal coalition, etc., and have put suspicion on the diagnosis of sinus tarsi syndrome.
In case of painful instability of the hindfoot after a trauma, we advise to perform every possible examination (clinical, X-Rays, Ct-Scan, Bone-Scan, MRI, arthroscopy). Only if all these remain negative, consider the diagnosis of sinus tarsi syndrome.

Charcot (neuro-arthropathic) foot

Jean-Martin Charcot has described first the neuro-arthropathy of the foot in 1868, in relation with the syphilis. Nowadays, the diabetes is the leading cause of this disease, whose etiology is still largely unknown. Mean age of diagnosis is 57, with the diabetes lasting usually for more than 10 years. No difference between male and female patients. Bilateralism occurs in 6-40%. Despite the increasing number of Charcot feet, this problem is generally poorly recognized and often poorly managed, leading to a high rate of amputations. The Charcot joint probably has both a vascular and a traumatic etiology. An acute trauma or repetitive microtraumas associated with the impaired sensation caused by the neuropathy are the start point of the architectural changes and joint destruction. The presence of excellent circulation is necessary. The Charcot foot may present as a fracture, but more commonly as multiple fracture-dislocations.
Evolution: Eichenholz (1966) has described three stages of development:

1. *Stage 1 or fragmentation:* acute inflammation with bone destruction and dislocation. Clinic: hyperemia, redness, hot swollen joints
2. *Stage 2 or coalescence:* beginning of the reparative process, with bone resorption and callus formation.
   Clinic: diminution of edema, warmth and erythema.
3. *Stage 3 or consolidation:* bone healing, usually with residual deformity.
   Clinic: "cold" foot, no swelling.

Clinical evolution without treatment lead to break down of dislocated joints, with a « rocker bottom » foot deformity, plantar ulcers, infection and eventually amputation.

The principles of conservative treatment are:

1. Achieve the third stage of the bony healing with minimal deformity allowing the use of near normal shoes or easily adaptable orthopaedic shoes
2. Minimize soft tissue problems and ulcerations, avoiding the development of an osteomyelitis leading to an amputation
3. Keep the patient as mobile as possible during the healing process.
4. Long period of treatment (normal X 3)

The conservative measures include progressive stages:

1. Rest and elevation of the foot to diminish the swelling and rule out osteomyelitis
2. Total contact cast (change every 5-7 days) or CROW (Charcot Restraining Orthotic Walker)
3. Weight bearing as tolerated and if no progressive foot deformation
4. Continue the cast/walker brace as long as the patient has not reached stage 3, clinically and radiologically (usually 4-6 months, but sometimes 12 months). Monthly radiographic controls
5. After consolidation, use of an ankle brace or adapted orthopedic shoes, and regular medical supervision.

Surgical treatment is indicated in:

1. Acute - stage 1-2
   a) failure of conservative treatment
   b) progression of deformity or associated osteomyelitis
2. Consolidated - stage 3
   a) recurrent ulcer or joint instability

and includes various techniques depending of the problem: A. debridement only or ostectomy, B. Ilizarov external fixator, C. joint fusion with strong plates or nails. Complications of surgery are post-operative infections, not rare and these may lead to amputation. Rate increases with co-morbidities, especially smoking and previous active infection. Non-union with rupture of implants are frequent, but it is very often well tolerated and allows walking either with a bracing (AFO) or an adapted shoeing.

Hallux valgus

Hallux valgus is the most common pathologic condition of the forefoot and much more often in women than in men. It is the cause of pain on the medial "bump", of transfer metarsalgia, and causes hammer toes. More that 150 operations have been described for hallux valgus management. They can be divided according to the localization:

1. Soft tissues
2. P1 osteotomies
   a. Akin
3. Distal MT1 osteotomies
   a. Chevron
   b. Reverdin
4. Mid-shaft MT1 osteotomies
   a. Scarf
5. Proximal MT1 osteotomies
   a. Crescentic
   b. Chevron
   c. Closing or opening wedge
   d. Ludloff
6. CMT1 arthrodesis (Lapidus)
7. MTP1 arthrodesis
8. MTP1 arthroplasties
   a. Brandes-Keller, Valenti, Mayo
   b. Prosthesis

Or according to the technique:

A. Open
B. Minimal invasive
C. Percutaneous

Hallux rigidus

Arthrosis of the metatarso-phalageal joint of the big toe can be idiopathic, microtraumatic (dancers), inflammatory (rheumatoid arthritis), due to a chronic misalignment (severe hallux valgus) or due to an osteochondritis. Pain and stiffness are the main clinical signs, together with the thickening of MTP1 joint (osteophytes). NSAID drugs, steroid intra-articular injection and orthotic may relieve symptoms. In case of persistent pain, surgical options include joint preserving procedures as osteotomies of P1 (Moeberg) or MT1 (Watermann-Green, Weil), joint debridment with cheilectomy (open or percutaneous), resection arthroplasties (Valenti, Brandès-Keller), MTP1 arthrodesis and prostheses. Arthrodesis of MTP1 joint is still the gold standard in advanced, stage 3 cases and shows a 90% of satisfaction rate, but positioning is demanding and it requires stability of the internal fixation.

Hammer toes

Surgical correction of hammer toes often requires an arthrodesis of the proximal interphalangeal (PIP) joint. Most of the time, the joint is maintained with a metallic pin for weeks, with an increased risk of infection, breakage, migration and discomfort for the patient. Furthermore, fusion is not always granted after pin removal. Use of internal devices could increase fusion rate, decrease complications and improve patient's comfort. Percutaneous surgery is an option to be evaluated, especially for metarsalgia.

Morton

Morton's syndrome is a very common diagnostic, maybe too often used: its real incidence is not well known and the prolific literature is controversial. It concerns an entrapment neuropathy of an inter digital nerve under the inter metatarsal ligament. It can be isolated or, more often, combined with overload pathology of the forefoot. The diagnosis is made essentially clinically, and can be confirmed by MRI. The conservative treatment, with adequate shoes, insoles, and steroid infiltration, is efficient, especially if the symptom lasts for less than one year. The aetiology must be treated. After failure of this approach, the surgical option must be evaluated carefully: the relatively « easy » procedure of removal of the nerve should not obviate the potential pitfalls, leading sometimes to difficult to manage pain and re operations. Options are injection of phenol and neurolysis by cutting the intermetarsal ligament, percutaneously or endoscopically.

Morton's nevroma surgery seems very "simple" but is actually very difficult with many complications, bad results and "recurrences":

%	Good	Bad	Re-do	Numbness	Normal shoes
Bennett,1996	85	15	21		
Dereymaeker 1996	81	19			30
Jarde, 1995	89	11		41	75
Assmus,1994	81.5	18.5		11.1	
Ruuskanen 1994	80	20	9		
Keh, 1992	93	7			

What are the reasons for these "bad" results?

1. Differential diagnosis is wide and may lead to wrong treatment: synovitis, bursitis, MTP arthritis, Freiberg's infarction, stress fracture, wart, mechanical hyperpressure, hyperlaxity of a MTP joint, tarsal tunnel syndrome, etc. In this situation, the so-call "recurrence" of pain is simply the consequence of the false treatment and the persistence of the etiologic problem.
   Treatment: Treat the cause of the pain.
2. Excision of the nerve is followed by the formation of a stump neuroma. This is a normal process, but if this plantar neuroma is too big or too distal, it will be very painful. *Treatment:* Second excision, more proximal, using the primitive dorsal approach or a plantar incision. In case of persistent problem due to a painful recurring neuroma, a redo with a tubular venous autograft could be the salvage solution.
3. Loss of sensation due to removal of the nerve is also normal, but may be the cause of bothering dysesthesia.
   *Treatment: N*o surgery, but conservative measures including pain killer, gabapentine, clonazepam, TENS, "trigger points" desensitization, specific insoles, etc.
4. The scar itself, if plantar, is sometimes source of painful intractable plantar keratosis. *Treatment:* Avoid plantar incision! Specific relief insoles. Surgery: excise the scar – plastic surgery.

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Trauma: Digital replantation
Indications & management

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Summary

Even though today replantation surgery has become a routine procedure, it still remains a delicate and demanding surgery that requires that the orthopaedic, plastic or hand surgeons involved have adequate training, experience and expertise in microsurgical techniques. The surgeons must also have at their disposal all of the necessary microsurgical armamentarium in order for digital replantation surgery to be possible. The indications, as well as the priorities for replantation procedures have been well established and documented, including formulated guidelines for thumb, single digit, multiple digit and mid palm amputations. For cases that face more complex problems, the surgeon should be aware of other alternative techniques, such as transpositional microsurgery and various other secondary reconstructive procedures. Although, replantation procedures have been simplified, a second surgical team should be present in the operating room to assist and facilitate the chief surgeon. The assisting team, in this two-team system, saves valuable surgical time by harvesting microvenous grafts, performing bone fixation or tendon repair among other things, while the chief surgeon focuses on revascularization. In addition, a well-trained anesthesia team familiar with replantation procedures should always be on standby to monitor a number of parameters related to either the type of anesthesia administered (general anesthesia, regional or combination) or other factors, such as drugs, room temperature, patient's body temperature, etc., all of which are closely related to the success of the replantation effort. A number of sophisticated post-operative measures are now available to follow the replanted digit and are invaluable in the patient's post-operative care. A plethora of methods are available for early identification of complications before they rapidly turn to an irreversible state and thus, allow for their immediate management. None-the-less, the presence of a member of the replantation team with the assistance of a nurse on a 24-hour basis is still widely accepted as the most beneficial means for avoiding an undesirable post-operative course of the replanted digit. Overall, the most significant guideline, which underlines the philosophy and trends of digital replantation today, reflects the current aim of not only ensuring the survival of the finger, but its functional use, as well. Experience dictates that this can be achieved only if the basic principles, indications and selection criteria, which have been described above, are adhered to.

Introduction

- 1968, Komatsu & Tamai – 1st successful replantation of an amputated thumb.
- Today, accumulated experience has made revascularization & replantation surgery a fairly routine procedure, provided that surgeons are well-trained in microsurgical techniques.
- Goal of all replantation efforts is targeted not only towards the survival of the amputated part, but mainly towards producing as close as possible normal functional ability.
- Well-defined selection criteria enable the surgeon to avoid procedures which lead to a surviving, but non-functioning digit on the one hand, and a plethora of secondary reconstructive procedures on the other hand.
- Fundamental to the success in replantation of a digit is not only a solid microsurgical technique for vascular microanastomosis, nerve coaptation and tendon repair, but also a clear understanding of the selection criteria.

Selection Criteria

- Well documented selection criteria have been established to assist the surgeon in screening patient eligibility for replantation.
- The functional outcome should be superior to that of a prosthesis or revision of the amputation. The criteria which aid the surgeon in predicting outcome can be divided into:
  1) Those factors related to the type of amputation and its characteristics;
  2) General factors related to the patient.

Classification of Amputations (based on the viability of the digit)

- *Complete Digital Amputations:* Amputated part is completely detached from the proximal stump; there is no tissue part interposed between the distal amputated part and the proximal stump.
- *Incomplete Nonviable Digital Amputations:* Both neurovascular bundles & entire or most of the venous network system are severed or severely damaged. The distal segment is connected to the proximal stump with either an islet of skin or a small segment of tendon or nerve. None of these tissue components are capable of ensuring the viability of the distal part.
- *Incomplete Viable Digital Amputations:* Assessed only after visualization under the operating microscope. Usually one digital artery and 1 or 2 dorsal veins remain intact.

Indications & Contraindications According to Type of Amputation

Thumb: High priority; When successful, results are better than any reconstructive procedure.

Single Digit: 3 major indications.

- level of the amputation - distal to the insertion of the flexor digitorum sublimis (superficialis). The digit immediately becomes functional as flexion of the middle phalanx by the intact superficialis tendon is possible.
- level of amputation at or distal of DIP joint. Replantation achieved with the anastomosis of one artery, while venous drainage can be provided by provoked bleeding or with the application of leeches.
- ring avulsion injuries Type II or IIIa. The flexor digitorum superficialis tendon remains intact & outcome almost always has good function.

Contraindications

- amputation at the level of the proximal phalanx or PIP joint, particularly avulsion or crush injuries. Almost always results in a nonfunctioning digit.

Multiple Digits: High priority. Most important consideration is the overall function of the hand.

- When amputated segments are severely mutilated and damaged, then efforts are aimed at replanting the least damaged digit segment to the most useful stump.
- When all of the digits are not replantable & thumb remains intact, the aim is to restore width of palm by replanting or transposing digits to the ulnar side. This augments grasp power of the hand and maintains light pinch.

Transpositional Microsurgery: transpostion & replantation of any digit to another stump which plays a more significant role in the function of the hand. 5 major indications

- *Multiple Digit Amputations* Including the Thumb: when thumb is not replantable either because it is too short or is extensively damage, the least damaged digit is replanted in the place of the mutilated thumb.]
- *Bilateral Thumb Amputations:* The thumb of the non-dominant hand which is less damaged or the least damaged digit is transposed to the thumb stump of the dominant hand for the sake of maintaining dexterity in that hand.
- *Bilateral, Symmetrical Digital Amputations:* Replantation effort is directed towards increasing the dexterity of the dominant hand by transposing digits over from the non-dominant hand.
- *Multiple Digital Amputations with the Thumb Intact:* digits are replanted towards the ulnar side of the hand, so as to preserve the width of the palm and consequently increase the power grasp of the hand.
- *Amputation of All Five Digits:* 2 goals: 1) replant & create a useful and functional thumb. 2) transpose the digits towards the ulnar side, to preserve width of the palm & power grip.

Mid Palm: ideal candidates for replantation & constitute an absolute indication. If replantation efforts are successful, hand functional ability is superior to any prosthetic device. Success is directly related to the level of the amputation. Greater success rate when amputation located at the level of the superficial or deep palmar arch, compared to those at the level of the common digital arteries.

General Indications & Contraindications

Age:

- Children- an attempt should be made to replant almost any amputated digit. If the reattached part survives, useful function can be predicted.
- Elderly- poor nerve regeneration & joint stiffness poses problems for good functional outcome. Good sensibility, strength and coordination is rarely achieved.

Mechanism of Injury

- Clean-cut "guillotine" type amputations are good candidates for replantation.
- Minor crush or avulsion amputations with minimal vascular injury are good candidates.
- Severely crushed or avulsed digits have extensive vascular, nerve and soft tissue damage and the predicted outcome is usually poor.

Time of Ischemia

- Warm ischemia or anoxia at 20o to 25oC produces irreversible necrotic changes to the muscle and soft tissues.
- Because digits lack muscle, the time allowed for warm ischemia is about 8 hours. By cooling the amputated part to 4oC, ischemia time for digits can be extended to up to 30 hours.

General Health of the Patient

- With major life-threatening injuries at the time of trauma, then replantation of digits may need to be postponed or even canceled.
- Certain diseases which adversely affect peripheral circulation (diabetes mellitus, autoimmune diseases, collagen vascular diseases, etc) often a contraindication.

Pre-operative Care of the Patient & Amputated Part

- After stabilization of other major injuries, bleeding from the stump is controlled using pressure. The patient is transported with a pressure dressing & no attempt to ligate or clamp vessels should be made. In cases where bleeding is persistent, a pneumatic tourniquet or cuff can be used.
- The amputated part, if contaminated, is gently rinsed in normal saline & wrapped with gauze, moistened in normal saline or Ringer's lactate. The wrapped part should then be immersed in normal saline in a plastic bag and the bag placed on ice.
- In incomplete amputations, the amputated part should be left attached to the stump with care taken to avoid rotation or pinching of the soft tissues which might further compromise any remaining flood flow.

Surgical Sequelae & Techniques in Replantation

- The entire sequelae that comprises a single digital replantation procedure is a series of complex & delicate operations for vessels, bone, tendons, nerve and skin.
- Surgical sequelae may vary somewhat according to level of the amputation & type of injury.
- 1st thorough cleansing & debridement, so that structures are identified
- Structures are repaired serially from the skeletal plane outwards, so that the deeper structures are repaired first, avoiding the sites of vascular anastomosis. In most cases, the repair of digits follows the following operative sequence:
  1) Neurovascular identification and labeling in the amputated part and stump;
  2) Tissue debridement;
  3) Bone shortening and stabilization;
  4) Extensor tendon repair;
  5) Arterial anastomoses; Survival is directly related to the successful anastomosis of both of the digital arteries, and two dorsal veins per patent digital artery.
  6) Venous anastomoses;
  7) Flexor tendon repair;
  8) Nerve repair;
  9) Soft-tissue and skin coverage.
- All of the structures are repaired primarily, including nerves unless a large nerve gap is present which necessitates a secondary nerve grafting procedure. Secondary reconstruction of structures would entail operating through repaired structures of the replanted part.

Surgical Preparation of Amputated Part and Patient for Replantation

- Two surgical teams: One team prepares the amputated part, while the other prepares the patient & the amputated stump.
- The amputated part is cleaned with normal saline & kept cool by placing it on a bed of ice.
- Debridement should be performed using the operating microscope or magnifying loupes. It is important to excise all necrotic and potentially necrotic tissue, as well as foreign bodies.
- The amputated part is carefully debrided & dissected to expose arteries, veins, nerves, tendons, joint capsule, periosteum and soft tissues which will save considerable time during replantation later. Digital vessels & nerves are identified & traced for 1.5 to 2 cm and tagged with 8/0 or 9/0 nylon sutures for later vascular and nerve repair.
- Most replantations can be performed under axillary brachial plexus block with bupivacaine, a long-acting local anesthetic. Regional anesthesia is preferred because of the increased vasodilation and peripheral blood flow due to the peripheral autonomic block.
- The stump is first cleansed with an antiseptic, such as povidone-iodine solution and irrigated with normal saline. Then the stump is debrided and neurovascular structures are identified and labeled with 8-0 or 9-0 nylon under magnification and tourniquet ischemia.
- Subcutaneous veins on the stump are often very difficult to locate, but to avoid venous congestion, it is critical that an adequate number of veins are identified for later patent anastomosis.

Bone Shortening and Fixation

- Bone shortening almost always proceeds osteosynthesis & vessel anastomosis.
- Shortening of the digital skeletal framework before replantation appears to be one of the best alternatives in achieving good end-to-end vessel anastomoses on healthy tissue and without tension. This also applies for digital nerve repair.
- The amount of bone removed ranges from 0.5 - 1 cm and varies according to the type of injury and the level of the amputation
- preferable to remove bone from the amputated part, so that if the replantation fails, length of the digit stump has not been sacrificied.
- Bone resection is followed by osteosynthesis, which allows for the healing of microvascular anastomoses and nerve sutures, as well as repaired tendons.
- Mini plates with screws, single lag screws, crossed Kirschner wires, a combination of intraosseous circlage wires and Kirschner wires, as well as intramedullary Kirschner wires are examples of the materials and techniques suitable for bone fixation.

Tendon Repair

Extensor Tendons:

- The extensor tendons are always repaired with an end-to-end suture technique directly after bone shortening and fixation.
- Suturing of the extensor tendons provides additional stability for the replanted digit
- Repair of the extensor tendons is always done primarily.
- Flexor Tendons:
- Rule of thumb: tendon repair is done directly only in very selected clean-cut amputations. In all other cases, repair is done as a secondary operation either with tendon grafts or using a two-stage flexor tendon reconstruction procedure.
- Care must be taken in retrieving the proximal flexor tendon stump, so as not to induce spasm or damage to the proximal arteries.
- If tenolysis is required, it should not be performed until 3-6 months after replantation, while secondary flexor tendon reconstruction using the two-stage silicone rod method can be performed about 3 months after replantation.

Digital Artery Repair

- It is preferable to repair both digital arteries.
- Critical for successful microvascular anastomosis are 1) solid microsurgical technique, and 2) anastomosis on normal intima with no tension.
- The artery should be dissected until normal intima is visualized under high-power magnification. If normal intima can not be approximated without tension, then the surgeon must consider either further bone shortening, or preferably the use of a vein graft.
- If the ends can not be anastomosed without tension, then an interpositional vein graft obtained from the palmar forearm should be used.
- With a patent anastomosis, the fingertip will begin to turn pink in a few minutes. Capillary refill and pulp turgor should be inspected.

Digital Vein Repair

- In order to repair two veins for each artery, veins may need to be mobilized or harvested.
- The most common error is anastomosis under tension or to waste time trying to repair very small veins. Only the largest veins should be anastomosed.

Digital Nerve Repair

- Repair of the digital nerves adheres to the same guidelines as with the repair of the flexor tendons within the tendon sheath.
- With clean-cut injury, direct end-to-end digital nerve coaptation is indicated.
- In all other situations, such as crush or avulsion type injuries, secondary procedures using a nerve graft or if the nerve gap is less than 2 cm, using a nerve conduit, are recommended.

Skin Coverage

- Once all of the structures have been repaired, hemostasis is imperative.
- The skin be loosely approximated with a few interrupted nylon sutures.
- Potentially necrotic skin is excised and the skin is closed with out tension.
- A local flap, split thickness graft, z-plasty, two-stage pedicle flap or free flap may be required to ensure coverage of the anastomosis site, as well as area of nerve and tendon repair.
- Fasciotomies are indicated if pressure or constriction occurs.

Dressing

- The wounds should be covered with strips of gauze moistened with antibacterial grease or petrolatum.
- It is essential that the strips are not placed in a continuous or circumferential manner which can potential constrict the replanted digit.
- A bulky dressing is applied, with the fingertips remaining exposed for clinical observation and temperature probes.

Postoperative Management and Rehabilitation

- Careful postoperative management is essential for a successful outcome.
- The room should be warm, as cooling can lead to cold-induced vasospasm.
- Cigarette smoking by the patients and visitors is strictly forbidden, as nicotine is a potent inducer of vasospasm. Cold drinks, as well as those with caffeine are restricted.
- Broad spectrum antibiotic (cephalosporins) are generally indicated for 5 to 10 days for patients with open injuries.
- High energy crush or avulsion injuries with extensive vessel damage depend upon adequate anticoagulant therapy for better patency. Among the agents commonly used are heparin, aspirin and low molecular weight dextran.
- Clinical evaluation should include color, capillary refill, temperature and turgor. Clinical evaluation should be performed continuously for the first three 24 hours postoperatively.

Complications

Acute complications:

- Inadequate perfusion is responsible for acute complications.
- Decreased skin temperature, loss of capillary refill, diminished turgor, or abnormal color in the immediate postoperative period indicate that the replanted digit is in jeopardy.
- When the area is cyanotic, congested and turgid, then venous insufficiency is present. If the problem is minor, it sometimes can be managed without having to reoperate. Congestion can be efectively relieved with the use of medicinal leeches..
- If normal perfusion does not return, the patient must be returned to the operating room within 4 to 6 hours after the appearance of inadequate perfusion. If the patient is returned with the first 12-48 hours, some failures can be salvaged by redoing the vein graft, removing the thrombus and grafting a previously unrecognized damaged vessel segment.
- Subacute and Chronic Complications:
- Subacute complications due to infection are fairly frequent in digital replantations, they rarely result in the loss of the replanted part.

- Pin tract infections are the most common and occur about four weeks after surgery. They can be managed by pin removal and administration of antibiotics.
- The most common chronic complications include cold intolerance, tendon adhesions and malunion. Cold intolerance improves over time.
- Tendon adhesions are frequent, resulting in limited motion. In severe cases, tenolysis can be performed after three months.

Conclusions

- Even though today replantation surgery has become a routine, it still remains a delicate and demanding surgery that requires adequate expertise in microsurgical techniques.
- Indications are well established with formulated guidelines for thumb, single digit, multiple digit and mid palm amputations.
- Although replantation procedures have been simplified, a second surgical team can save valuable surgical time by harvesting microvenous grafts, performing bone fixation or tendon repair among other things, while the chief surgeon focuses on revascularization.
- The current aim which underlines the philosophy in digital replantation today is ensuring not only the survival of the finger, but more importantly its functional use as well.
- Experience dictates that this can be achieved only if the basic principles and indications which have been described above are adhered to.

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Congenital anomalies: Classification & management

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Summary

Reconstructive microsurgery in the management of congenital anomalies is aimed at providing the ability to control placement of the hand in space, good skin cover with adequate sensibility and satisfactory power grasp and precision handling. Early correction of skeletal alignment is vital. As such, extra bones, malpositioned bones, and fusions between adjacent bones should be dealt with in order to allow normal growth and development. Although several congenital upper extremity anomalies may be treated using various microsurgical techniques, microvascular autotransplantation in reconstructive surgery of congenital anomalies brings versatility to reconstruction of the upper limb that has previously not been available. These procedures allow for transplantation of skin flaps in one stage, and the transplantation of vascularised joints and/or growth centers. In addition, they offer the opportunity to reconstruct digits by transplantation of homologues from the foot. Long-term studies have shown the usefulness of microvascular toe transfer in the treatment of adactyly with the incorporation of the transferred digit into grasp-and-pinch function. Morbidity to the donor site is almost negligible, and the functional improvement to the hand is reasonably good considering the young age of the patients. Functional results are limited by the lack of full motion, soft-tissue contractures, sensory recovery, and the delay in cortical reeducation. The use of free fibular transfer for long bone deformities of the forearm has been shown to provide bony union as well as growth. In selecting a reconstructive procedure, surgeons must consider various factors such as, patient age, vessel availability, and lack of other possible reconstructive options. In reconstruction of congenital hand anomalies, the importance of digit positioning to provide prehensile pinch and grasp as the ultimate goal needs to be emphasized so that opposing fingers rather than cosmetic fingers result in effective hand use. In the selection process among reconstructive alternatives the surgeon must consider factors related to both aesthetic improvement of the hand, as well as long-term functional return.

Introduction

■ **Embryology**

- Bud appears – 25th day
- Full development – 56th day

■ **Tissue element development**

- Skeletal elements – 5 wks
- Joints & tendons – 6 wks
- Ligaments – 8 wks
- Ossification – 9 wks
- Synovial tissue – 11 wks

■ **Normal Development**

- Age 1 yr – Hand fully integrated. Good grasp & pinch control
- Age 3 yrs – Prehension accuracy, coordination refinement & increased strength

■ **Congenital deformities = structural abnormality present at birth**

- Anomalies of musculoskeletal system = broad spectrum. Single vs multiple. Major vs minor clinical significance.
- Incidence: 1 of 626 newborns (0.16%). Of which 90% have no functional impairment, and 10% have functional impairment. (Finland incidence 0.18%. Study by Vilkki; Greece incidence 0.19%. Study by Soucacos)
- 10-15% are associated with anomalies to organ systems (cardiovascular, craniofacial, genitourinary.

Congenital anomalies: Classification & management

Classification

- There are numerous systems for classification of upper-extremity anomalies. Based on embryology, anatomy, etc.
- Based on Swanson (1968), IFFSH and ASSH propose: Eliminates confusion from Greek & Latin terms. Defines anomalies according to embrionic failure during development and uses clinical diagnosis for categorization. 7 Categories
  - Failure of formation
  - Failure of differentiation
  - Duplication
  - Overgrowth
  - Undergrowth
  - Constriction ring syndrome
  - Generalized abnormalities & syndromes

Failure of formation

- Arrest of development
- Complete or incomplete
- Transverse (congenital amputation) Can be at any level
  - Absent limb or absent finger
  - Common levels of arrest are upper third of forearm, wrist, metacarpal, phalangeal
  - Absence of hand = acheria; absence of finger = adactyly. Often difficult to distinguish from constriction band syndrome. Nail remnant disqualifies patiens from this category.
- Longitudinal arrest
  - Preaxial – varying degrees of hypoplasia of thumb or radius
  - Central
    divided into typical & atypical types of cleft hand
  - Postaxial – varying degrees of ulnar hypolasia to hypothenar hypoplasia
  - Intercalcate longitudinal arrest – various types of phocomelia
  - Includes:
    - ◦ Missing ray (eg thumb aplasia)
    - ◦ nubbins
    - ◦ phocomelia – the functional terminal element is present. Various types:
      1. hand attaches to shoulder (forearm & arm deficient)
      2. forearm attaches to shoulder (arm deficient)
      3. hand attaches to arm (forearm deficient)
    - ◦ Radial club hand
    - ◦ Ulnar club hand

Failure of Differentiation

- Failure of separation of parts
- Soft tissue involvement – syndactyly, trigger thumb, Poland syndrome, camptodactyly
- Skeletal involvement – various synostoses & carpal coalitions
- Congenital tumorous conditions – include all vascular & neurological malformations. (eg radio-ulnar synostosis, symphalangism [stiff proximal interphalangeal joints with short phalanges] camptodactyly, arthrogryposis, syndactyly
- Basic anatomic units are developed
  - Shoulder
    - ◦ Undescended scapula
  - Arm
    - ◦ Proximal radio-ulnar synostosis

- Forearm
  - Distal radio-ulnar synostosis
- Hand
  - Syndactyly – one of the most common anomalies in the hand. Classified according to completeness (complete, incomplete) and presence of bony union.
  - Clinodactyly – deviation of finger as a result of an abnormally shaped middle phalanx.
  - Camptodactyly – almost exclusive to Caucasians. Presents either in infancy or adolescence. Usually bilateral and affects little finger.

Duplication

- Splitting of embryonic parts
- Ulnar or radial side
  - Polydactyly
  - Mirror hand – classic presentation is duplication of ulna, with no radius, 7-8 digits with no thumb.

Overgrowth

- Gigantism, hyperplasia
- Limb or part (finger, hand or arm)
- Involves skeleton or soft tissue
- Macrodactyly, megalodactyly
- Hemihypertrophy

Undergrowth

- Incomplete development
- Hypoplasia
- Brachysyndactyly
- Brachydactyly, Brachyphalagia
- Short metacarpals
- Madelung's deformity (abnormal distal radial growth)

Constriction Ring Syndrome

- Represents a disruption of deformation sequence subsequent to annular bands of chorionic tissue encircling the limb. It has a low incidence of associated anomalies.
- Clubfoot is the most common association
- Limbs or digits
- Streeter hypoplasia – occurs with or without lymphedema; involves amputation at any level

Generalized skeletal abnormalities

- Unclassified category
- Syndromes with skeletal malformations
- Dwarf, Marfan

Management

- Surgical targets
  - Good power grasp
  - Precision handling
  - Good skin cover
  - Hand placement control
- Timing of surgery. Early surgery is performed by definition with the 1st 2 yrs. Advantages include full potential for development & growth, less scarring, easier & early incorporation of reconstructed part, anatomic adaptation, and reduced psychologic consequences.
  - Disadvantage: technical difficulty.
- Conservative management (90% of congenital anomalies require no surgery!)
  - Night splints
  - Physiotherapy
  - Prostheses
    - Functional
    - Cosmetic

Failure of Formation

- Transverse
  - Cosmetic prostheses
  - Toe-to-thumb
  - Digital lengthening
  - If metacarpal elements are present, objective is to create a basic hand:
    - Mobile ray on radial side
    - A cleft
    - A post on ulnar side or at least one ray on the opposite side
- Longitudinal
  - Phocomelia – best treated with prosthesis.. Radial or ulnar deviation of the hand may need centralization.
  - Toe-to-thumb
  - Polisization
    - For thumb aplasia
    - Good grasp & pinch function

Failure of Differentiation

- Syndactyly
  - Separation of digits, provision of a lined commissure, avoidance of scars

Duplication

- Polydactyly
  - Excision
- Mirror hand
  - Correction begins proximally with correction of elbow. Excision of one of the ulnar heads. Wrist extension is restored by tendon transfer or the wrist can be arthrodesed. In the hand, resection of the accessory preaxial middle & little fingers and then using the accessory ring digit as a thumb with a modified pollicization procedure.

Overgrowth

- Macrodactyly
  - Objective is to diminish length & bulk without compromising sensation or vascularity.
  - Includes: staged debulking, epiphysiodesis or total physeal resection, shortening procedures, partial amputation or ray amputation.

Undergrowth

- Brachyphalangia
  - Digital lengthening

Constriction Ring Syndrom

- Toe-to-hand

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Distal Radius Fractures: Evolution in the treatment

The recent developments of many osteosynthesis and fixation devices are the reason or the consequences of the rapid changes in the treatment of distal radial fractures (DRF). From a relative conservative policy of treatment according to the expected good results of these injuries as reported by Colles and many authors we are facing now a very aggressive treatment with open reduction and internal fixation. Confusion is very often done between the different fractures types, the character of the injury and not least the patient groups, their age and activities level or expected activity levels. The use of a standardized treatment protocol may make it possible to select the patients with DRF for appropriate treatment. The chosen treatment will guarantee in each case the expected results with an almost, but not fully, normalized function at one year. All fracture types independently their severity will reach the same good results. There is no evidence based reason, with the actual knowledge in 2009 to apply a standardized treatment with volar locking plate to all patients and/or type of DRF. Further studies on this subject are needed and might change the actual standard of care in the future. We always have to be aware of the morbidity of the applied

Proximal Interphalangeal fractures (PIP): A challenge of treatment

Dorsal fracture-dislocations of the proximal interphalangeal joint (PIP) are common injuries especially among young active individuals. The mechanism of injury is often a longitudinally transmitted compressive force, combined with hyper-extension. In the classification of these fractures the size of the fractured articular surface of the base of middle phalanx is measured to predict the potential instability of the PIP joint throughout the full arc of motion. Treating these injuries one has to a) maintain articular congruity by reconstruction of the "cup shaped geometry" of the base of middle phalanx, b) maintain the stability of the PIP joint, mainly by restoring the buttress of the volar lip of the middle phalanx, c) achieve early functional range of motion and d) avoid post-traumatic arthritis of the PIP joint. In non comminuted fractures: Excellent or good results, with active ROM of PIP joint reaching or even exceeding 80o, can be expected in acute cases with only one large volar lip fragment. In comminuted fractures: an extreme fragmentation of the volar lip makes anatomical reconstruction of the articular surface impossible by open reduction and mini screw fixation. Indirect reduction and minimally invasive fixation with cerclage/tension wire have been used, sometimes with good results. External fixation devices distracting the joint surfaces to unload have been used. a promising but technically demanding method of PIP reconstruction. The anatomical similarity noticed between the volar lip of the base of the middle phalanx and the dorsal part of the hamate articulating with the base of the forth and fifth metacarpal make an anatomical. mechanical an physiologic modality of fracture reconstruction.

Wrist Instability: To recognize a pathology

In order to recognize pathology, the physical examination of the wrist remains the primary tool to be used. A careful assessment, including inspection, observation of use, motion and abnormalities, palpation with eventually reproduction of pain, comparison with the contra lateral side is an absolute requirement. The clinical examination can of course not be dissociated of the patient history and both together lead to hypothesis of eventual pathology. The pathology can than after be confirmed or denied by the help of other more or less invasive investigation procedures like radiographs, CT, MRI or arthroscopy. Beside the experience of the physician the absolute knowledge of the anatomy is the key point of the diagnosis. Instability of the wrist can only be defined in relation with the stability concept and be in relation with the normal kinematic of the wrist in motion understanding the change of the scaphoid position in relation with the lunate with the so called VISI and DISI deformations

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ELBOW

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Introduction

The most authoritative and comprehensive textbook about the elbow is certainly The Elbow and Its Disorders, 4th Edition, Elsevier 2008 by Bernard F. Morrey, MD. In it, the student will find a compilation of the most recent knowledge of all aspects of elbow pathology.
For the latest in fracture fixation techniques the reader is invited to visit the AO surgery reference site: AO surgery reference: http://www.aofoundation.org. Another most useful publication containing pertinent facts related to orthopaedics and musculoskeletal in general trauma is the AAOS Comprehensive Orthopaedic Review. Jay R. Lieberman, MD, Editor 2009 Rosemont, IL, American Academy of Orthopaedic Surgeons.

Facts about the elbow

The distal humerus is an arch subtended by two columns of equal importance. The trochlea is a pulley like structure covered by cartilage in a 300° arc. The articular portion of the distal humerus in the lateral plane is inclined 30° anterior with respect to the axis of the humerus, the frontal plane is tilted 6° into valgus, and in the transverse plane is rotated medially about 5°. The capitellum is a half sphere covered anteriorly with cartilage. The radial head is asymmetric and has two articular interactions: The proximal ulno-radial joint and the radio-humeral joint. It has approximately a 240° of articular cartilage coverage which leaves 120° of non cartilage covered area amenable to hardware fixation. The head and neck have an angle of 15° in valgus. The proximal ulna has a coronoid process that has an area equivalent to the radial head. There is no cartilage in the middle of the sigmoid notch. The joint is angled 30° posteriorly in the lateral plane; 1° to 6° in the frontal plane. The carrying angle is the angle between the humerus and the ulna with the elbow extended fully and it varies between 11°-14° in men and 13°-16° in women. The capsule attaches anteriorly above the coronoid and radial fossae and just distal to the coronoid. Posteriorly it attaches above the olecranon fossa, follows the columns and distally attaches along the articular margins of the sigmoid notch. The normal elbow has a range from 0° or slightly hyperextended to 150° of flexion, pronation is 75° and supination is 85°. A 3° to 4° varus-valgus laxity has been measured during F/E. The rotation of the forearm is around an oblique axis passing through the proximal and distal radio-ulnar joints. The primary static stabilizers of the elbow are the ulno-humeral articulation and the collateral ligaments. The secondary static stabilizers are the capsule, the radiohumeral articulation and the common flexor and extensor tendon origins. The dynamic stabilizers are all the muscles that cross the elbow (Anconeus, triceps, brachialis). Finally all forces that cross the elbow joint are directed posterior and this has implications in surgical procedures around the elbow, in the design of elbow prosthesis, and in rehabilitation programmes.
-The Elbow and Its Disorders, Editor BF Morrey, 4th Edition, Elsevier 2008.

Approaches to the elbow

__Lateral approach__

Kocher (radial head fracture, lat collat reconstruction)
Interval between the anconeus and extensor carpi ulnaris
Column (Stiff elbow)
Extensor carpi radialis longus and distal fibers of the brachial radialis elevated from the lateral column and epicondyle. Brachialis muscle separated from the anterior capsule; safe if the joint penetrated at the radiocapitellar articulation. Triceps may be elevated posterior giving access to the olecranon fossa.

<u>Anterior approach</u>

Henry (PIN, proximal radius, tumors)

After an appropriately curving incision to avoid the flexor crease, brachioradialis and brachialis are gently separated to find the radial nerve. Follow the nerve to the arcade of Frohse where the motor branch plunges into the supinator to course dorsally in the forearm then elevate supinator from its radial insertion laterally thus protecting motor branch in the supinator mass.

<u>Medial approach</u>

Over the top Hotchkiss approach

(Coronoid fracture type 1: transolecranon suture)

50:50 split in the flexor-pronator mass anterior to the ulnar nerve.

Natural split : Taylor and Scham

(Coronoid fracture type 2-3 with plate fixation).

Elevation of the entire flexor-pronator mass, from the dorsal aspect to the volar aspect.

<u>Boyd Posterolateral Exposure (Radial head, proximal radius)</u>

The ulnar insertion of the anconeus and the origin of the supinator muscles are elevated subperiosteally. More distally, the subperiosteal reflection includes the abductor pollicis longus, the extensor carpi ulnaris, and the extensor pollicis longus muscles. The origin of the supinator at the crista supinatorus of the ulna is released, and the entire muscle flap is retracted radially, exposing the radiohumeral joint. The posterior interosseous nerve is protected in the substance of the supinator, which must be gently retracted

Posterior approach (Fractures distal humerus, arthroplasty, stiff elbow)

Posterior approach with extensile exposure of the distal humerus:

- Bilaterotricipital approach (Alonso-Llames) with lateral and medial retraction of the triceps
- Triceps Splitting (Campbell)
- Olecranon osteotomy: Extra-articular, chevron or straight.
- Triceps sparing elevation of triceps according to Gschwend (osseous) or Morrey-Bryan (subperiosteal).
- Triceps reflecting anconeus pedicle approach (TRAP) *O'Driscoll.*

-The Elbow and Its Disorders, 4th Ed, Elsevier 2008 Ed. Morrey BF.

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Fractures and Dislocations

<u>Fractures of the distal humerus</u>

These fractures are relatively rare and constitute about 2% of all fractures, but represent a ⅓ of all elbow fractures. They most commonly occur in patients in the 6th decade and above and are frequently associated with osteoporosis. These fractures are frequently comminuted and operative fixation is therefore technically difficult. Fractures of the distal humerus are articular fractures characteristically **unstable** and prone to displacement. Only in exceptional circumstances is non-operative treatment warranted. For the best results **operative intervention** providing accurate reduction and stable fixation is therefore indicated in these complex fractures. Before intervening careful physical examination is necessary and specifically ascertaining the neurovascular status of the involved extremity. **Compartment syndromes,** a menacing complication with a devastating outcome must be diagnosed early and aggressively treated with fasciotomy. The goal of the treatment is to obtain a stable construct restoring the anatomy and allowing for early motion so as to restore function and strength to the elbow joint.

The anatomy of the distal humerus is complex and for practical purposes the **two column concept** is the best suited. It may be described as two columns, the lateral and the medial, providing the stable structure upon which the articular epiphysis, trochlea and capitellum, is anchored.

Many **classifications** exist; the one best suited being the AO classification which includes type A or extra-articular fracture patterns, type B or partial intra-articular fractures and type C, the most complex, with intra-articular separations and comminution involving the whole joint. To aid in classification it may be useful to obtain x-rays of the contralateral elbow, to perform CT scanning and perhaps most helpful to obtain traction X-rays. Certain fractures such as capitellum fractures are difficult to diagnose and therefore all imaging modalities must be obtained in case of doubt. All these modalities will aid in the diagnosis of the fracture pattern and influence the approach and fixation modalities.
AO surgery reference: http://www.aofoundation.org.

Once the decision to operate is taken, it must be decided on how the patient should be **positioned during** the intervention. This will depend on the fracture pattern and on the patient's condition. The decision should be made in accordance with the anaesthesiologists. For fractures involving the lateral column only a supine approach will be chosen while for fractures involving the medial column or both columns a decubitus lateral position or a ventral position may be necessary to perform a posterior approach, it must be noted that in these positions it will be nigh impossible to access to the front of the elbow, however having to do so is very rare. Also, the surgeon must be very careful of the positioning of the contralateral limb, head and neck, to avoid injury due to compression.

The use of a **tourniquet** is debatable, if the fracture is uncomplicated and the operation is anticipated to be short, a tourniquet will provide a bloodless field and will be useful. In case of a complex fracture, paradoxically, I tend not to use a tourniquet which might have to be inflated for too long a time and I prefer instead to perform careful haemostasis during the approach and operate in the driest field possible.

The **lateral approach** will be directly on the lateral column dissecting off sharply the insertions of the brachioradialis and the extensor carpi radialis longus and brevis from the lateral supracondylar ridge in front and the triceps in the back. The common extensor origin is then sharply lifted off of the epicondyle anteriorly and if necessary the anconeus posteriorly. Proximal extension must be done with caution because of the radial nerve. The joint capsule is incised and elevated to view the capitellum and the radial head.

The **medial approach** is useful for fractures of the epitrochlea and the ulnar nerve must be carefully identified before inserting screws.

The **posterior approach** will be useful for fractures involving the medial or both columns and with intra-articular fractures of the trochlea. The incision will be midline, swerving laterally around the olecranon and in line with ulnar shaft. In all cases the **ulnar nerve** must be visualized and protected. The nerve is easy to find, lying almost subcutaneously at the medial edge of the triceps three finger breadths above the olecranon, once identified it is followed over the epitrochlea into the common flexor mass avoiding injury to the motor branch of the flexor carpi ulnaris that it penetrates between its ulnar (posterior) and humeral (anterior) heads. At the end of the operation it must be decided whether to transpose the nerve anteriorly into a subcutaneous pocket or not. Personally, I avoid this if possible because it renders redo surgery extremely difficult if the whereabouts of the transposed nerve are not exactly described. The next difficulty is exposing the fracture. If there is widespread comminution of the trochlea it is wise to proceed to an **osteotomy of the olecranon** which may be chevron shaped or transverse. The near cortex is cut with an oscillating saw for precision but the articular cortex should be broken off with an osteotome allowing for perfect reposition. At the end of the intervention the olecranon must be repositioned and fixed using a tension band with K-wires or a single 6.5 mm spongiosa screw. In the case the hole may be drilled before osteotomy ensuring a good reposition. In cases where the fracture of the trochlea is sagittal with no comminution **a bilateral tricipital reflecting approach** as described by Alonso-LLames may be used or alternatively a **triceps reflecting anconeus pedicle approach** (TRAP) as described by O'Driscoll may be used. It is best to avoid triceps cutting (V-Y) approaches for they tend to weaken the extensor mechanism without really being efficacious for exposure.

Isolated fractures of the **capitellum** are approached laterally and must be repositioned and fixed with two posterior to anterior small fragment 3.5 mm lag screws or with Herbert type screws.
Isolated fractures of the **epitrochlea** are approached medially and fixed in place with a lag screw after careful reposition. The ulnar nerve

must be protected.

Fractures of the lateral column are approached through a direct lateral approach. Plate fixation will be needed to augment the screw fixation, usually small fragment implants placed on the posterior aspect of the lateral column will provide adequate fixation.

Both column fractures without articular involvement need a posterior approach and can be addressed through a bilaterotricipital Alonso-LLames or TRAP approach. Both columns are identified and fixed to the articular epiphysis using a lateral 1/3 tubular plate for the medial column and a posterior 3.5 reconstruction plate for the lateral column. Newer anatomically contoured plates have now reached the marketplace and may also be used.

Both column fractures with articular involvement are the most difficult fracture patterns and need an extensive posterior approach with an accompanying olecranon osteotomy for visualisation. It is necessary to reconstruct the distal epiphysis first. Most of the time the fracture is sagittal line and adequate reduction is easily obtained and held with a lag screw placed in such a way as not to interfere with the ulnar nerve. Sometimes in case of comminution it is necessary to place an intercalary bone graft so as not to squeeze and narrow the epiphysis which renders the joint incongruent. One the joint surface has been reconstructed it is then possible using various types of implants to fix both columns. In general a 1/3 tubular plate placed medially on the trochlear column and a posterior 3,5 mm reconstruction plate on the lateral side will provide sufficient fixation. Both plates should be at right angles to each other, the medial plate lying in the sagittal plane and the lateral plate in the frontal plane. Other options include multiple small plates (2.7 mm) or more recently the use of contoured anatomic plates some equipped with locking holes which provide angularly fixed screws. As a general rule it is wise to avoid provisional reduction with too many K-wires as these will interfere with the placement of the definitive implants and reduction will be lost when these are put in place while having to remove the provisional fixation. These fractures tax the anatomical and biomechanical knowledge of the surgeon, as well as his imagination and skill and are amongst the most challenging of articular fractures to undertake.

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Comminuted intra-articular fractures in osteoporotic bone. In cases of comminuted fractures of the distal humerus occurring in elderly, osteoporotic, low demand patients it is now a recommended option to place a cemented **Total Elbow Arthroplasty.** Because the epicondyles and their ligamentous attachments are cannot be reconstructed, the chosen prosthesis must provide intrinsic stability. Excision of the radial head must be performed if it impinges upon the prosthesis. Contra-indications include open fractures or a high infectious risk because of extensive soft tissue damage. The technique is demanding and the surgeon must be experienced in TEA for elective procedures before embarking on this intervention. The results are reported to be satisfactory in the literature; however the complication rate is high for this type of operation.

-Gambirasio R, Riand N, Stern R, Hoffmeyer P. Total elbow replacement for complex fractures of the distal humerus. An option for the elderly patient. J Bone Joint Surg Br. 2001 Sep;83(7):974-8.

Comminuted open fractures of the distal humerus. In rare instances one is confronted with a major soft tissue injury with an underlying fracture. In case of Gustilo I and II open fractures the treatment is to debride and wash out the wound and proceed with internal fixation as if it were a closed injury. Whenever possible the opening should be incorporated in the approach and the wound closed over suction drainage at the end of the procedure. Appropriate antibiotic prophylaxis should be started after swabs are obtained for microbiological investigations including culture and sensitivity. In the face of Gustilo III open fractures a **humero-ulnar external fixateur** bridging the fracture zone and immobilising temporarily the joint is a reasonable and useful option. Beware of the radial nerve crossing the humeral diaphysis laterally approximately 7cm above the elbow joint. It is recommended to insert the pins of the external fixateur through a small open incision after having visualized and protected the radial nerve. The fixateur pins, usually a half frame, should be placed as far from the fracture zone as possible so that the pin tracts will not interfere with future osteosynthesis. Once the elbow is bridged, the priority is restoring the integrity of the soft tissue envelope with the help of a plastic surgeon if deemed necessary. Once the soft tissue envelope is restored it may be advisable to remove the fixateur and to proceed with a stable reconstruction of the joint surfaces so as to begin motion and avoid a stiff and painful elbow.

Rehabilitation consists in splinting to protect the soft tissues but with immediate assisted ***active*** motion. After 6 to 8 weeks the soft tissues are less swollen the splint may be removed and careful use with non weight carrying may be tolerated.

Fractures of the radial head

Fractures of the radial head represent around 2 % of all fractures and 33% of all elbow fractures. They usually occur after a fall on the slightly flexed outstretched elbow with the hand in supination. The patient complains of immediate pain in the lateral region of the elbow after a fall. There is often a palpable fluctuation outwardly bulging over the radio-humeral joint due to haemorrhagic effusion and active prono-supination is painful or impossible. To assess the amount of displacement the humero-radial joint is aspirated and lidocaïne is injected into the joint. If smooth, non-grating, active or passive prono-supination is possible this is a reliable sign that the fracture is minimally displaced and that non-operative will lead to a satisfactory outcome, otherwise surgical treatment is mandatory if painless motion is to be restored.

Anatomically and biomechanically, the radial head is part of the **forearm articular complex** including the proximal radio-ulnar joint, the interosseous membrane and the distal radio-ulnar joint that allows prono-supination of the forearm. The **radiohumeral joint** also participates in the flexion/extension mobility of the elbow joint. Furthermore the radial head is involved in the stability of the elbow joint and plays the role of a **secondary stabilizer**. If the ulnar collateral ligaments and the distal radioulnar joint are intact, the radial head plays no role in the stability of the elbow and may therefore safely be removed if necessary. However, in the absence of the radial head and disruption of the distal radioulnar ligaments (Essex-Lopresti lesion), the radius will migrate proximally and more so when there is an associated tear of the interosseous membrane. In these circumstances a relative over-lengthening of the ulna will occur at the wrist entailing painful dysfunction. Also, in the absence of the radial head, valgus instability will occur at the elbow if the ulnar collateral ligament is torn or elongated.

Fracture classification of radial head fractures:

Various classification schemes have been proposed:

Mason Classification:

Type I:	Non-displaced
Type II:	Displaced marginal fractures
Type III:	Comminuted fractures
Type IV:	Associated with elbow dislocation

Hotchkiss modification

Type I:	No surgery
Type II:	Displaced but fixable
Type III:	Displaced and unfixable

As a general rule displaced fractures need surgical intervention, minimal displacement may benefit from Open Reduction and Internal Fixation (ORIF) and highly displaced or comminuted fractures may necessitate excision in case of a stable Distal Radio-Ulnar Joint and intact interosseous membrane and prosthetic replacement if these conditions are not met.

Approach

The approach is basically lateral starting obliquely from the supracondylar ridge over the radio-humeral joint and trough the Kocher interval between the anconeus and the extensor carpi ulnaris. This protects the motor branch of the radial nerve (Avoid placing a Hohmann type retractor over the anterior neck of the radius) and the approach is sufficiently anterior to spare the ulnar collateral ligament which will not be inadvertently severed. The capsule is revealed and an arthrotomy is performed exposing the radial head. The annular ligament is spared.

Technique

Reconstructible fractures: After assessment they are fixed using small fragment 2.0 or 2.7 AO or Herbert type screws. Sometimes the use of a mini blade plate type of implant may be necessary.

Radial head excision: If excision is necessary be sure that all fragments are excised by reconstructing the head on the instrument table. The head should be removed at the level of the annular ligament. The elbow and wrist should be closely assessed for stability and the lateral collateral reconstructed if necessary.

Prosthetic replacement: It is necessary to provide stability by inserting a radial head prosthesis in cases of fracture dislocations with either frontal plane instability such as with extensive tearing of the lateral collateral ligaments or with longitudinal instability with tearing of the interosseous membrane or DRUJ. Today, the accepted prosthesis is metallic with or without a moving or floating (bipolar) head and a stem that may be cemented or non-cemented. In some cases the prosthesis may be left permanently in place while in other instances such as in very young patients it may be useful to remove the prosthetic head used as a temporary spacer once healing of the ligamentous complex has occurred. Silastic implants once in vogue are now generally abandoned because of the risk of a destructive synovial inflammatory response due to fragmentation of the prosthesis leading to the accumulation of irritative particulate matter. Furthermore biomechanical studies have shown that these prostheses are not stiff enough to allow anatomic healing of torn ligaments.

Rehabilitation

As general rule rehabilitation must be begun early and motion should be started within days of the intervention in case of operative treatment or diagnosis in case of conservative treatment. After a few days of rest start by gentle ***active*** flexion exercises going from 90° to 110° then progress with ***active*** extension exercises ranging from 120° to 30° as tolerated. After two to three weeks gentle ***active*** prono-supination exercises are begun. An articulated brace is useful for protection in cases of instability

The ESSEX LOPRESTI injury

This injury was described in 1951 by Essex-Lopresti and associates as a severely comminuted fracture of the radial head with tearing of the interosseous membrane and disrupting the DRUJ. The diagnosis is clinical and radiological. X-rays of the whole forearm are necessary. The radial head must imperatively be fixed or replaced with a prosthesis and the DRUJ has to be stabilized with a cross pin left in situ for 4 to 6 weeks.

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Fractures of the olecranon

Fractures of the olecranon usually occur after falls directly on the elbow point. They are frequently seen in the osteoporotic patient.

There are various classifications; the most popular are the Mayo classification:

Type I: Undisplaced

Type II: Displaced but stable elbow (Noncomminuted: A /Comminuted: B)

Type III: Displaced and unstable elbow (Noncomminuted: A / Comminuted: B)

The AO classification (Complex: includes the proximal forearm segment: radius and ulna):
A: Extra-articular fractures
B: Intra-articular fractures
C: Fractures of both olecranon and radius

A treatment plan must be elaborated. The great majority of these fractures are displaced and the question arises as to what is the best suited technique.

Approach
The surgical approach is straightforward. The ulna is subcutaneous; the patient may be in a supine or lateral decubitus position with the arm resting on a support. A tourniquet may be used. The incision follows the shaft of the ulna and some recommend arcing the incision radially to avoid the tip of the olecranon and also to avoid a scar over the ulnar nerve.

Technique
Clearly transverse fractures are best treated by a technique associating K-wires and tension band cerclage such as described by the AO Group. The technique must be meticulously followed and especially the placement of the K-wires must be parallel, 5 to 6 cm long, and the tip should be into the opposite cortex distally to the coronoid and the ends must be bent at 180° and deeply buried into the triceps and olecranon. Comminuted fractures will require a plating technique (3.5 LCP or DCP plates) augmented by longitudinal screws (so-called homerun screws). If the fracture is oblique and is near the coronoid a compression screw will be most useful. The main drawbacks of these techniques lie in the high reoperation rate that all authors mention. K-wires tend to back out and must be carefully followed and plates usually present some degree of discomfort and are best removed after adequate consolidation. A more recently described **complication** is the interference of K-wires or screws placed in the proximal ulna with the proximal radius. Some implants are too long and either impinge or are screwed into the radial head or bicipital tuberosity. This is not an easy diagnosis post-operatively and freedom of prono-supination must be carefully ascertained at the end of the surgical reconstruction.

Rehabilitation
The patient is placed into a backslab at 80° of flexion and gentle active flexion and extension exercises are started as tolerated. The olecranon is protected for 6 to 8 weeks before any weight bearing exercises are started.

Fractures of the coronoid
This is usually associated with dislocations of the elbow. Regan and Morrey have classified these injuries into:

Type I:	Fracture of the tip
Type II:	Less than 50% of the height of the coronoid
Type III:	More than 50%

A and B types signify no or associated dislocation.
Some have added a:

Type IV:	Fracture of the sublime tubercle.

Type I fractures are generally stable and do not need fixation if the elbow is stable. Types III and IV need surgery to insure stability of the elbow because the medial collateral ligament attaches to the medial coronoid and instability will occur if the bony fragments are not fixed. More recently O'Driscoll has modified this classification: into

Type 1:	Tip fractures
Type 2 :	Anteromedial fractures
Type 3 :	Base of coronoid fractures

In this classification all types 2 and 3 need fixation and especially if associated with a dislocation or a radial head fracture. Plain x-rays and preferably a CT scan should be used for making the diagnosis and classifying the lesions. Small lesions can be fixed by transolecranon

sutures. The fragment is approached from a medial incision in an "Over the top" as approach described by Hotchkiss Large fragments are approached by a posteromedial route.
In very unstable elbows a hinged external fixateur device will provide stability while allowing early motion.
-Regan W, Morrey B. Fractures of the coronoid process of the ulna. J Bone Joint Surg Am 1989;71:1348–1354.)
-O'Driscoll SW, Jupiter JB, Cohen MS, Ring D, McKee MD. Difficult elbow fractures: pearls and pitfalls. Instr Course Lect 2003;52:113–134.
-Hotchkiss RN. Fractures and dislocations of the elbow. In: Rockwood CA, Green DP, eds. Rockwood and Green's fractures in adults. Vol 1. 4th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 1996:929–1024.

Dislocation of the elbow
The mechanism is usually a fall on the outstretched hand with the elbow in a varus position. The primary lesion is a tear of the lateral collateral ligament from the lateral humeral insertion and as the mechanism of dislocation the capsule is then torn anteriorly , the coronoid may be damaged by the ram effect of the trochlea and finally the medially collateral may be torn also, leading to a very unstable position. In 5 to 10% of cases a fracture of the radial head may be associated as well as more rarely a fracture of the capitellum. Neurovascular injuries occur infrequently but must be looked for. The median nerve may be stretched by the front riding humerus, and this is the most frequent neurological injury, however the radial nerve and the ulnar nerve may also be damaged. The brachial artery may suffer an intimal tear or a rupture while it is stretched out over the protruding distal humerus and very rarely the skin may split leading to an open injury. A compartment syndrome is always a possibility and the patient must be monitored.
Dislocations of the elbow are classified as anterior (rare), posterior (most common) and divergent (very rare the radial head will be separated from the ulna and the annular ligament is torn).
The elbow, after proper radiographic and clinical assessment should be reduced, general anaesthesia may be necessary, and tested for stability: varus, valgus and postero-lateral. Postero-lateral rotatory instability occurs when the ulno-radial bloc dislocates off of the humerus laterally in supination and upon reduction in pronation a clunk is heard and felt. The elbow is then flexed to past 90° and held in a splint in pronation. An X-ray is then taken to determine that the reduction is adequate. After 5 to 7 days the elbow is moved, first in flexion then extended as tolerated in an active-assisted mode. A hinged splint may be worn and after 3 to 6 weeks all immobilisation if motion has returned and the patient feels stable all splints are removed.
Indications for surgery range from incarceration of a bony fragment in the joint space, to vascular impairment or gross instability usually associated with a coronoid fracture (see above). Late contracture or heterotopic bone may also lead to surgery at a later stage if mobility is severely limited (>30° of flexion deformity). Late instability may also necessitate surgery and the use of a hinged fixator allowing stable distraction of the joint surfaces and concomitant mobilisation.
-O'Driscoll SW, Morrey BF, Korinek S, An KN. Elbow subluxation and dislocation: A spectrum of instability. Clin. Orthop. Relat. Res. 280:186, 1992

Medial instability of the elbow
Throwing athletes may develop medial instability due to medial ulnar collateral ligament (MUCL) stretching out or tearing. The patient may experience a pop or a tearing sensation during a throw. Physical examination includes looking for ulnar neuritis and Tinel's sign. The elbow is stressed in valgus at 25° of flexion and the MUCL is palpated for taughtness. Further diagnostic imaging using plain stress-test x-rays, dynamic ultrasound or Arthro-MRI will fine tune the diagnosis. MUCL reconstruction using a figure of eight tendon graft as described originally by F Jobe and refined and modified more recently may then be performed.
- Safran M, Ahmad CS, El Attrache NS. Ulnar collateral ligament of the elbow. Arthroscopy 21:1381, 2005.

Postero-lateral rotatory instability of the elbow
After injury or dislocation of the elbow the patient may develop a condition where recurrently he has the impression of the elbow popping or giving way or even dislocating. The symptoms are on the lateral side where the patient often has pain and discomfort. Clinical testing will reproduce the sensation of pain and instability when the elbow is stressed in valgus and supination. An audible pop can occur during this manoeuvre. It signifies that the radius and the ulna although firmly attached by the annular ligament, slip out laterally as a unit from the capitellum because of a tear of the ulnar lateral collateral ligament that laterally unites the humerus to the supinator crista of the lateral ulna. Repair may be accomplished by a tendon graft uniting the humerus to the supinator crista of the ulna and passing under the radial head.

-Nestor BJ, O'Driscoll SW, Morrey BF. Ligamentous reconstruction for posterolateral rotatory instability of the elbow: J Bone Joint Surg Am. 1992;74(8):1235-41.

The stiff elbow

The normal elbow has a range from 0° or slightly hyperextended to 150° of flexion, pronation is 75° and supination is 85°. The stiff elbow becomes a clinical problem when the functional arc accepted in flexion/extension diminishes beyond 130°-30°- 0. Very severe stiffness occurs when the total arc is less than 30°, severe stiffness is when the arc is between 31° and 61°, moderate between 61° and 90° and minimal when the arc is greater than 90°. A 100° range of pron/supination (50° pronation and 50° of supination) is necessary for normal function although as a rule lack of pronation is in general less tolerated than lack of supination.

If no bony abnormalities are present the **lateral column procedure**, where the anterior and posterior contracted capsule is excised from a lateral approach after detaching the distal fibers of the brachioradialis and the extensor carpi radialis longus is recommended. **Medial release** detaching the flexor-pronator mass is performed in case of arthritic osteophytes, caring for the ulnar nerve. It may be combined with the lateral column procedure. For the rehabilitation it is important to immobilize during night-time the elbow in the position of greatest motion loss. If extension is to be gained the elbow should be immobilized in extension during night-time and flexion during the day.

For more complex conditions with bony deformity, ectopic bone, major osteophytes overgrowth or posttraumatic conditions a posterior approach with of sculpturing of deformed bony surfaces, excision of new bone formation and sectioning of restraining tissues will have to be performed. In some of these cases a hinged uni or bilateral humero-ulnar external fixator allowing controlled motion will need to be used. The ulnar nerve will need special care and transposition may be indicated in some cases. The radial nerve may be at risk when external fixation is used.

Some authors in cases of minimal or moderate stiffness have used arthroscopic release techniques

-Ball CM, Meunier M, Galatz LM, Calfee R, Yamaguchi K. Arthroscopic treatment of post-traumatic elbow contracture. J Shoulder Elbow Surg 2002;11:624-629.

-Mansat P, Morrey BF. The column procedure: A limited lateral approach for extrinsic contracture of the elbow. J Bone Joint Surg Am 1998;80:1603-1615.

-Morrey BF. The posttraumatic stiff elbow. Clin Orthop Relat Res 2005;26-35.

Tendon ruptures and athletic injuries

Distal Biceps Tendon Ruptures

The distal biceps is the most commonly ruptured tendon around the elbow. This usually occurs with heavy lifting. The patient reports hearing a pop or a crack in the anterior region of his elbow. In the hours that follow the injury an ecchymosis may discolour the antecubital fold. The biceps muscle belly does not retract immediately because it is held down by the lacertosus fibrosus. The patient will have near normal flexion extension strength but will complain of weakness in supination. In an active population the treatment is usually surgical and a two incision reattachment technique as described by Morrey yields satisfactory results. When using this technique care must be taken not to come into contact with the proximal ulna when bringing the distal biceps through the ulno-radial space so as to avoid an osseous synostosis. Gentle flexion-extension exercises follow the surgery and at 6 weeks a full return to activity is permitted.

Rupture of the **brachialis** and of the **triceps** tendons have been reported. These are rare injuries and the best surgical treatment consists in suturing the ruptured tendons.

-Papandrea RF: Two-incision distal biceps tendon repair, in Yamaguchi K, King GJW, McKee O'Driscoll SW : Advanced Reconstruction Elbow. Rosemont, IL, American Academy of Orthopaedic Surgeons, 2006, pp 121-128.

Lateral Epicondylitis (Tennis Elbow)

The most comprehensive description of the pathoanatomy of epicondylitis is Nirschl's. The essentially this is an overuse lesion causing tearing of the extensor carpi radialis brevis tendon at its distal humerus insertion. Diagnosis is made by eliciting pain on palpation of the lateral epicondyle, wrist extension against resistance as long finger extension against resistance will also produce pain at the elbow in case of epicondylitis. All other conditions leading to elbow pain such as carpal tunnel, radial nerve entrapment under the arcade of Frohse or

radiohumeral arthritis should be eliminated. Adjunct imaging such as plain x-rays will not be specific and MRI may be used to image a tear or an edematous area in the region of insertion. Treatment consists of modifying activity, steroidal infiltration, adapted physiotherapy and in case of a long duration of symptoms surgical excision of the ECRB tendon, situated under the Extensor Carpi Radialis Longus tendon. Most authors recommend open procedures although success has been reported using arthroscopic techniques. A characteristic angiofibroblastic hyperplasia-tendinosis has been described by Nirschl which characteristically demonstrates little inflammatory cells. Postoperative treatment consists of a protective splint followed by gentle motion as tolerated with full function possible 6 to 8 weeks postoperatively.
-Kraushaar BS, Nirschl RP. Tendinosis of the elbow (tennis elbow). Clinical features and findings of histological, immunohistochemical, and electron microscopy studies. J Bone Joint Surg Am 1999;81:259-278.
-Nirschl RP, Pettrone F. Tennis elbow: The surgical treatment of lateral epicondylitis. J. Bone Joint Surg Am. 1979; 61:832.

Medial Epicondylitis
Rarely, in the competitive athlete pain will develop following overuse of the flexor-pronator complex. Again the treatment should first be conservative. If symptoms persist surgical excision of the diseased part of the medial conjoint tendon of the flexor-pronator complex may be considered. In some cases a transposition of the ulnar nerve completes the procedure.
-Vangsness CT, Jobe FW. Surgical treatment of medial epicondylitis. Results in 35 elbows. J Bone Joint Surg Br. 1991;73(3):409-11.

Osteochondritis Dissecans
Rare condition affecting mostly skeletally immature patients involved in receptive throwing sports. Symptoms include pain, flexum deformity or catching and locking. This should be differentiated from Panner disease which is an osteochondrosis not requiring treatment. A classification has been evolved that spans from the simple cartilage fissures (I) to the detachment of a large fragment (IV) of cartilage. Treatment is at first conservative with activity modification and if not successful can go, depending on severity, from simple drilling of the lesion to complex mosaicplasty.
-Baumgarten TE, Andrews JR, Satterwhite YE: The arthroscopic classification and treatment of osteochondritis dissecans of the capitellum. Am J Sports Med 1998;26:520-523.

The degenerative elbow
Primary osteoarthritis
This entity is relatively rare in the elbow and affects about 2% of the population, usually encountered in active males in their fifties. Patients complain of pain often with an inflammatory component and stiffness also plays an activity limiting role. Treatment modalities are conservative (NSAIDS, physiotherapy, braces). If this fails arthroscopic debridement has been advocated. Joint sparing procedures such as the Outerbridge-Kashiwagi procedure may be performed. This consists of an open posterior ulno-humeral arthroplasty where the olecranon fossa is trephined and the osteophytes are removed from the coronoid and the olecranon. In patients over 65 years of age an arthroplasty, resurfacing or hinged may be used.

Inflammatory arthritis
Rheumatoid disease affecting the elbow should be treated by conservative means and recent progress with anti-TNF drugs have very much slowed down the destructive process. In stage Larsen 1 and 2 synovectomy may be indicated and in stage Larsen 3 and 4 an arthroplasty may be used: Resurfacing in the case of a stable elbow and hinged if the stability is questionable.
Total elbow arthroplasty has a high complication rate, ranging up to 40% with infection at the forefront. In the longer term hinged arthroplasties tend to loosen and resurfacing arthroplasties tend to dislocate.
-Antuna SA, Morrey BF, Adams RA, O'Driscoll SW: Ulnohumeral arthroplasty for primary degenerative arthritis of the elbow: Long-term outcome and complications. J Bone Joint Surg Am 2002;84:2168-2173.
-Gramstad GD, Galatz LM: Management of elbow osteoarthritis. J Bone Joint Surg Am 2006;88:421-430.
-Wada T, Isogai S, Ishii S, Yamashita T: Debridement arthroplasty for primary osteoarthritis of the elbow: Surgical technique. J Bone Joint Surg Am 2005;87:95-105.
-Little CP, Graham AJ, Carr AJ: Total elbow arthroplasty: A systematic review of the literature in the English language until the end of 2003. J

Bone Joint Surg Br 2005;87:437-444.

Osteochondromatosis

This is a condition leading to the presence of multiple intra-articular loose bodies in the elbow due to a multitude of synovial niduses. Some authors believe this disease to be borne of a defect of differentiation of the mesenchyme of the original limb bud. These totipotent cell populations will differentiate into the specialized tissues (synovium, cartilage, bone) constituting the joint. Anomalies in differentiation give rise to the condition where cartilage cells grow and coalesce within the synovium, detach and fall into the joint. Other theories mention the growth and ossification, in synovial fluid, of cartilage fragments detached from degenerative cartilage in case of osteoarthritis. The clinical presentation is pain often accompanied by locking or catching within the elbow. Diagnosis is straightforward when the cartilaginous bodies are ossified. MRI or CT with arthrography may be useful if the disease is in the stage before the loose bodies are ossified. Treatment is 80% successful either by open or arthroscopic techniques. The condition may lead to later osteoarthritis if it is not already a precursor condition of this disease.

-Kamineni S, O'Driscoll SW, Morrey BF. Synovial osteochondromatosis of the elbow. J Bone Joint Surg 2002;84B(7):961-966

Septic olecranon bursitis

This is a potentially life threatening condition caused by a septicaemia originating from an infected bursa under tension. Generally seen in debilitated patients but can arise without a clear cause or after minor trauma in an otherwise healthy individual. Diagnosis is clinical with standard laboratory findings such as high white cell count, left shift of white blood cells, high sedimentation rate and elevated C-reactive protein levels. Organisms found are generally staphylococcus or streptococcus. In mild cases treatment may be antibiotics and splinting. In more severe cases it is mandatory to incise the bursa and leave open, to immobilise in a splint and after a few days to perform a closure secondarily. During the treatment period appropriate IV and oral antibiotics are administered.

-Pien FD, Ching D, Kim E. Septic bursitis: Experience in a community practice. Orthopaedics 1991; 14:981

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Foreword

In the AO manual that covers all important fixation techniques the reader will fact pertinent facts related to the topic at hand: *AO Principles of Fracture Management. Second expanded edition, TP Rüedi, RE Buckley, CG Moran. Georg Thieme Verlag; 2 Har/Dvdr edition (2007).* For the latest in fracture fixation techniques the reader is also invited to visit the AO surgery reference site: *AO surgery reference: http://www.aofoundation.org*. Another most useful publication containing pertinent facts related to orthopaedics and musculoskeletal in general trauma is the *AAOS Comprehensive Orthopaedic Review. Jay R. Lieberman, MD, Editor 2009 Rosemont, IL, American Academy of Orthopaedic Surgeons*. For surgical approaches the most useful reference is without doubt: *Surgical Exposures in Orthopaedics: The Anatomic Approach. Hoppenfeld S, deBoer P, Buckley R. Lippincott Williams & Wilkins; Fourth Edition 2009.*

Introduction

The forearm must be considered as a whole functioning joint allowing pronation of 75° and supination of 85°. The interosseous membrane plays a major stabilising role.
-AAOS Comprehensive Orthopaedic Review. Jay R. Lieberman, MD, Editor 2009 Rosemont, IL, American Academy of Orthopaedic Surgeons.

Classification of forearm fractures

The AO classification is popular. It classifies the fracture patterns of radial and ulnar shafts as type A (simple, transverse or spiral) type B (wedge with a butterfly fragment) and type C (segmental or comminuted fragments). Open fractures are classified according to Gustilo and Anderson: Type I inside-out (< 1 cm), Type II outside-in (> 1cm), Type III A (open but osseous coverage possible), type III B (open necessitating a local or free flap), Type III C any open fracture with vascular injury.
Specific to the forearm are the Monteggia fracture pattern (Fracture of the ulna with dislocation of the radial head).
Bado classification:
I Anterior radial head dislocation and proximal ulnar shaft fracture (apex anterior)
II Posterior or postero-lateral radial head dislocation and proximal ulnar shaft fracture (apex posterior)
III Lateral radial head dislocation and proximal ulnar shaft fracture (apex posterior)
IV Anterior radial head dislocation and proximal ulnar and radial shaft fracture (apex posterior)
-Konrad GG, Kundel K, Kreuz PC, Oberst M, Sudkamp NP. Monteggia fractures in adults: long-term results and prognostic factors. J Bone Joint Surg Br. 2007;89(3):354-60.

Also specific to the forearm is the **Galeazzi** fracture pattern where the radius shaft is fractured along with a dislocation of the distal radio-ulnar joint (DRUJ). Suture of the triangular ligament or pin fixation of the DRUJ are indicated if after fixation of the radial shaft gross instability is still present.
-Rettig ME, Raskin KB. Galeazzi fracture-dislocation: a new treatment-oriented classification. J Hand Surg Am. 2001;26(2):228-35.

The Essex-Lopresti lesion combines a comminuted fracture of the radial head along with disruption of the interosseous membrane causing a relative overlengthening of the ulna at the wrist. (see Elbow section).

-Perron AD, Hersh RE, Brady WJ, Keats TE. Orthopedic pitfalls in the ED: Galeazzi and Monteggia fracture-dislocation. Am J Emerg Med. 2001 May;19(3):225-8.
AO Principles of Fracture Management. Second expanded edition, TP Rüedi, RE Buckley, CG Moran. Georg Thieme Verlag; 2 Har/Dvdr edition (2007).
Gustilo RB, Mendoza RM, Williams DN. Problems in the management of type III (severe) open fractures. A new classification of type III fractures. J Trauma 1984, 24:742-746.
Gustilo RB, Anderson J. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: Retrospective and prospective analyses. J Bone Joint Surg Am 1976;58:453-458.

Clinical presentation

A deformed extremity is present. Look for neurovascular injuries (radial nerve) carefully before any manipulation of the injured extremity. Plain X-rays including the shoulder and elbow are generally sufficient in acute traumatic cases. MRI, CT, Bone scintigraphy are useful in special situations such as chronic infection, metastatic or primary tumors.

Conservative treatment

There is practically no place for conservative treatment in adult both bone forearm fractures. Isolated fractures of the ulnar shaft may be treated by functional bracing but the rate of non-union remains high and many authors recommend immediate plate fixation

-Mackay D, Wood L, Rangan A. The treatment of isolated ulnar fractures in adults: a systematic review. Injury. 2000;31(8):565-70.

Surgical Approaches

Anterior (Henry) approach

Anatomic approach but with some soft tissue stripping. Allows exposure of the whole radius.

Dorsal Thompson approach

Danger to the Posterior Interosseous Nerve (PIN).

http://www.wheelessonline.com/ortho/dorsal_approach_thompson

Direct approach

The direct approach is best suited for the ulna.

-Mekhail AO, Ebraheim NA, Jackson WT, Yeasting RA. Vulnerability of the posterior interosseous nerve during proximal radius exposures. Clin Orthop Relat Res. 1995 Jun;(315):199-208.Erratum in: Clin Orthop 1997;(334):386.

Operative treatment indications

IM Nailing

Difficult to guarantee stable fixation and anatomic fixation with these devices.

-Anterograde

Nails for the ulna are in use and being developed

-Retrograde

Nails for the radius may be used

Plating

3,5 mm plates should be used and never semi or third tubular type plates. 6 cortices on each side of the fracture should be used. Some authors

External fixation

In case of open fractures an external fixation may be applied. For the ulna the pins may be applied closed but for the proximal radius an open approach allowing to identify the pertinent neurovascular structures should be performed.

-Hertel R, Pisan M, Lambert S, Ballmer FT. Plate osteosynthesis of diaphyseal fractures of the radius and ulna. Injury. 1996;27(8):545-8.

-Chapman MW, Gordon JE, Zissimos AG. Compression-plate fixation of acute fractures of the diaphyses of the radius and ulna. J Bone Joint Surg Am. 1989;71(2):159-69.

-Lindvall EM, Sagi HC. Selective screw placement in forearm compression plating: results of 75 consecutive fractures stabilized with 4 cortices of screw fixation on either side of the fracture. J Orthop Trauma. 2006;20(3):157-62; discussion 162-3.

Degenerative arthritis

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Degenerative arthritis of the elbow occurs in between 1-3% of the population. It has been shown to be associated with heavy manual work and occurs much more commonly in males rather than females.

The condition is associated particularly with degenerative change affecting the radio-capitellar joint with joint space narrowing whereas the ulnar trochlea joint is more often preserved. This part of the joint however is associated with osteophytes at the coronoid and tip of the olecranon.

It has been suggested that the condition is associated with a progression from normal aging to degenerative change.

Most frequently patients will present with aching pain in the elbow often associated with some restriction of elbow movement. Loss of extension is more commonly noted than loss of flexion.

Patients may also have pain associated with maximal flexion and extension and if loose bodies are present they may also experience locking pain.

The treatment options compromise conservative measures through to surgical intervention. The conservative treatment involves the use of simple analgesia and anti-inflammatory tablets.

If locking is a particular problem arthroscopy and removal of the loose bodies is indicated. In addition arthroscopy may also allow a capsular release with the result that improvement in flexion and extension may be achieved. Osteophytes can also be removed.

Open surgical procedures that have been described including the Oughtibridge-Kashiwagi (ulnar humeral arthroplasty) procedure which involves fenestrating the thickened olecranon fossa membrane.

In patients over the age of 70 who are no longer undertaking heavy manual tasks a total elbow arthroplasty may also be indicated.

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Basic anatomy

The shoulder consists of four joints, the sterno-claviclular, the acromio-clavicular, the gleno-humeral and the thoraco-scapular joint. The latter is not a proper joint but assists in the total range of motion corresponding to 30° of flexion-extension. Motion in the sterno- and acromionclavicular joints is small and consists of rotation. Most of the shoulder motion occurs in the gleno-humaral joint and consists of both flexion-extension and rotation inwards and outwards. The shoulder is the most mobile joint in the body. The normal motion is flexion 160°, abduction 160°, adduction to reach the opposite shoulder, external rotation 75° and internal rotation to Th 5-6.

The gleno-humeral joint has a large head articulating with a small and flat socket that does not cover the head. The surface of the glenoid is just 1/5 of the surface of the humeral head. This means that the stability of the joint is totally dependent of the function of the surrounding soft tissues: the glenoid labrum, the rotator cuff, the long head of the biceps muscle and to low pressure in the joint cavity. Also the scapula stabilising muscles, trapezius, rhomboids, levator scapule and serratus anterior contribute to shoulder stability and function. The most important muscle for shoulder function is the deltoid that provides strength and endurance in motion of the arm.

Approaches to the shoulder

Deltopectoral approach

The deltopectoral approach is the most commonly used for open shoulder surgery. It goes from the clavicle to the insertion of the deltoid on the humerus just lateral to the coracoid process following the interval between the deltoid and the pectoralis major. It may be used in its full length but usually one only needs the proximal part or less. After opening of the skin and subcutaneous tissue the cephalic vein is held laterally together with the deltoid muscle and the pectoral muscle medially. The subscapular muscle is transacted close to its insertion and the joint capsule opened. When closing the incision a careful repair of the subscapularis is important.

Lateral, transdeltoid approach

The lateral, transdeltoid incision is mainly used for surgery on the acromio-clavicular joint, open acromioplasty and rotator cuff repair. The skin incision follows the Langer lines along the acromion. Underneath the anterior and middle deltoid bellies are separated and freed sub-periosteally from the acromion. Then the subacromial space is entered and the acromion, a-c-joint and rotator cuff can be addressed. When closing a good repair of the deltoid on the acromion is of great importance.

Posterior approach

The posterior approach is not so commonly used but is practical for posterior instability, most scapular fractures and can be used for arthroplasty. The incision frees the deltoid from the scapular spine and then the infraspinatus muscle is separated from the teres minor. The tendon of the infraspinatus is transacted close to the insertion on the humerus and the posterior joint capsule opened.

Clinical diagnosis

The diagnosis of degenerative condition of the shoulder is based upon a good clinical examination evaluating motion, strength and weakness of the shoulder muscles, instability of the sterno-claviclular, the acromio-clavicular and the gleno-humeral joints and certain clinical tests. The routine examination should include the Neer or Hawkins's test for impingement, Jobe's test for supraspinatus and lift off test for subscapularis weakness and apprehension test for instability. In addition tenderness and adduction pain in a-c-joint should be tested.

Radiology

Conventional x-rays with AP- and lateral films and special a-c-joint views are the basis for diagnosis of shoulder disorders. Ultrasound examination by an experienced examiner is good for rotator cuff pathology. MRI should always be preceded by conventional x-ray and is primarily a study of the soft tissues. For detailed diagnosis of the skeleton CT gives the best information.

Arthroscopy

Today arthroscopy is primarily a therapeutic technique and pure diagnostic arthroscopies are rarely indicated. MRI usually provides sufficient and similar information in a non-invasive way.

The degenerative shoulder

Primary osteoarthritis

This entity is not uncommon in the shoulder. Its most often affects the a-c-joint and less common the gleno-humeral joint. Arthritic changes in the a-c-joint are a common find on x-ray but need not be symptomatic. Radiological arthritis in the gleno-humeral joint is usually symptomatic. Patients complain of pain and limited motion. X-ray films show and decreased joint space and typical inferior osteophyte formation. Treatment modalities are initially conservative (NSAIDS, physiotherapy). When conservative treatment fails a-c-joint arthritis is operated with resection of the most lateral 0.5-1 cm of the clavicle. This procedure gives pain relief but does not affect shoulder function. For gleno-humeral arthritis arthroplasty is indicated. Both hemiarthroplasty and total joint replacement are used although the latter is preferred when rotator cuff function is intact and glenoid bone stock is enough preserved to permit fixation of a component.

Cuff tear arthropathy

A special form of osteoarthritis in the shoulder is seen in combination with massive rotator cuff tears and is called cuff tear arthropathy. It is characterized by advanced arthritic changes, superior migration of the humeral head and absence of cuff function. Standard total shoulder replacement has an increased risk of glenoid loosening so hemiarthroplasty with or without an extended head is used. Alternatively prosthesis with reversed design can give a good function. This prosthesis has the head fixed to the glenoid and the cup in the humerus thus medialising the centre of rotation which facilitates arm elevation by the deltoid muscle alone. The lack of rotator cuff function is thus overcome.

Inflammatory arthritis

Rheumatoid disease often affects the shoulder. Modern pharmacological treatment is usually successful and recent progress with anti-TNF drugs have very much slowed down the destructive process. Synovectomy and arthrodesis was used earlier but today arthroplasty is the procedure of choice when the drug treatment fails. The choice between hemi- and total shoulder replacement is decided by the degree of glenoid destruction and rotator cuff function. With intact rotator cuff and glenoid total replacement is preferred. When the humeral head still is intact a resurfacing prosthesis on the humerus can be a good alternative to avoid a stem down in the diaphysis in case an elbow prosthesis is in place or indicated later.

Septic arthritis in the shoulder

This is most common in patients with a compromised immune system such as rheumatoid arthritis, post organ transplantation or during chemotherapy. It can be a potentially life threatening condition caused by a septicaemia and should be treated as such. Diagnosis is clinical with standard laboratory findings such as high white cell count, left shift of white blood cells, high sedimentation rate and elevated C-reactive protein levels. Joint aspiration reveals the causing bacteria. Organisms found are generally staphylococcus or streptococcus. In mild cases treatment may be antibiotics but in more severe cases it is mandatory to clean out the joint arthroscopically or by open surgery. During the treatment period appropriate i.v. and oral antibiotics are administered.

Adhesive capsulitis

Adhesive capsulitis is also called frozen shoulder. It is an idiopathic disease characterized by pain and progressive contracture of the gleno-humeral joint. The disease affects the joint capsule but the underlying cause is not known.

The disease starts insidiously with slowly increasing shoulder pain especially at night. After 2-6 months increasing stiffness at the gleno-humeral joint is noted. Both active and passive motion is reduced and can progress until the joint is completely stiff. This phase takes 3-9 months. The pain then starts to decrease slowly and the mobility of the shoulder comes back over a period of 3-12 months. Adhesive capsulitis thus takes 12-24 months from start to end full recovery is usually achieved. The treatment is symptomatic with analgesics and physiotherapy aiming at preserving the motion. Arthroscopic release of the joint capsule may be indicated when the diagnosis is clear in order to improve motion and shorten the natural history.

Impingement syndrome

Impingement syndrome is a pain condition in the shoulder. The name was introduced by Neer who believed the cause to be a conflict between the acromion and coraco-acromial ligament and the subacromial bursa and the rotator cuff on arm elevation. Bigliani-Morrison defined three types of acromial shape where the more curved the acromion is the more common is impingement. This etiology has later been challenged. Impingement syndrome is characterized by pain on raising the arm and when doing overhead work. Night pain and difficulties sleeping on the affected side is typical. It exists on its own or in connection with rotator cuff tears. The diagnosis can be established by the patient's history and a clinical examination. Special clinical test are the Neer test and the Hawkins' test which when positive produce the impingement pain. Injection of a local anaesthetic subacromially should take away the pain and make the impingement test negative. Standard x-rays may be normal or show curved acromion, sometimes with osteophytes at the tip, and/or arthritic changes in the a-c-joint with inferior osteophytes. MRI may show impression on the rotator cuff by the skeletal changes.

Initially impingement syndrome is treated with pain medication, subacromial injection of steroids and physical therapy. If non-surgical therapy fails an acromioplasty is indicated. This means increasing the subacromial space by resection of the tip and bottom surface of the acromion changing the form from curved to flat. Any inferior osteophytes in the a-c-joint are also resected. In Neer's original description of the operation the coraco-acromial ligament was also resected but later studies have shown that this is not necessary. An acromioplasty may be combined with lateral clavicle resection and with rotator cuff repair. Acromioplasty can be performed arthroscopically or open and today the former technique is dominating. Rehabilitation after the operation consists of a structured training programme and the outcome may take up to six months to achieve.

Rotator cuff tears

With normal ageing the rotator cuff becomes thinner and weaker. The tendon tissue degenerates and tendinosis and partial tears occur. They can progress to full thickness ruptures without symptoms but more common is that it is associated with pain and weakness on elevation and external rotation. Rotator cuff tears are more common with increasing age. A trivial trauma or load can change a partial tear to a total rupture. Cuff tears also occur in younger individuals but then usually after a substantial trauma. Dislocation of the shoulder is associated with cuff rupture in patients over 40 years of age.

Typical clinical symptoms are pain that aggravates with overhead activities and which often disturbs sleep. Weakness on elevation and external rotation and sometimes loss of those motions are also typical. Jobe´s test (Empty can test) for loss of supraspinatus strength. On the other hand full range of motion is possible even with massive total ruptures.

Diagnosis is made by the history and clinical examination. Plain x-rays may show cranial displacement of the humeral head relative to the glenoid. MRI is diagnostic for the size of the rupture and which tendons are involved. It also shows the condition of the muscle bellies which atrophy with long standing rupture. The muscle is infiltrated by fat and becomes non-functional.

Non-surgical therapy consists of physiotherapy aiming at strengthening the shoulder muscles and anti-inflammatory drugs. Subacromial steroids injections may give temporary pain relief. When this therapy fails to give sufficient pain decrease surgery is indicated. For patients with no pain but reduced motion and strength surgery is usually not indicated since the outcome regarding these parameters is less predictable.

Surgery aims at repairing the torn tendons and reattaches them to the humerus. The repair can be made arthroscopically for minor tears or mini-open (a combination of arthroscopic debridement and mobilization and open suture through a small transdeltoid incision. Larger tears demand an open repair. If the rupture is massive cuff and the cuff can't be repaired a tenotomy of an intact long head biceps tendon may reduce pain. Acromioplasty is usually performed to increase the subacromial space and remove impingement on the repaired cuff.

For patients in whom the loss of motion is a big problem improvement can be achieved with latissimus dorsi transfer or with a reversed shoulder prosthesis.

Rehabilitation after cuff repair consist of a structured training programme initially focused on gaining motion and after six to eight weeks

strengthening exercises ar added. The final outcome may take six to twelve months to achieve.
Recommended reading

REFERENCES

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3. *Matsen-Lippitt: Shoulder Surgery: Principles and Procedures. 1st ed., Saunders, 2003.*

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Shoulder Girdle Trauma

Foreword

For shoulder pathology the major reference is: T*he Shoulder, Fourth Edition. Editors CA Rockwood, FA Matsen, MA Wirth, SB Lippitt. 2009, Philadelphia, Saunders Elsevier. In the AO manual that covers all important fixation techniques the reader will fact pertinent facts related to the topic at hand: AO Principles of Fracture Management. Second expanded edition, TP Rüedi, RE Buckley, CG Moran. 2007, Georg Thieme Verlag. For the latest in fracture fixation techniques the reader is also invited to visit the AO surgery reference site: AO surgery reference: http://www.aofoundation.org. Another most useful publication containing pertinent facts related to orthopaedics and musculoskeletal trauma is the AAOS Comprehensive Orthopaedic Review. Jay R. Lieberman, MD, Editor 2009 Rosemont, IL, American Academy of Orthopaedic Surgeons. For surgical approaches the most useful reference is without doubt: Surgical Exposures in Orthopaedics: The Anatomic Approach. Hoppenfeld S, deBoer P, Buckley R. Lippincott Williams & Wilkins; 2009, Fourth Edition.*

Clavicle fractures

Clavicular fractures are some of the most common fractures accounting for 5% to 10% of all fractures and 35% to 45% of shoulder girdle injuries.
The clavicle struts the shoulder girdle.
Clavicular fractures are the result of falls, rarely direct trauma and rarely secondary to metastatic disease.
Clinical examination shows deformity of the shoulder girdle; a careful neurovascular examination must be performed due to the vicinity of fragile structures deep to this unprotected and subcutaneous bone.
Diagnosis necessitates an AP X-ray of the clavicle and often an AP view of the whole shoulder girdle will be of help to comparatively determine the amount of displacement. In some rare cases a CT will define the fracture.

Fractures of the clavicle are divided **into proximal third, mid-third and distal third.**

Proximal third fractures

Usually conservative treatment will be sufficient, if displaced will benefit from fracture fixation, preferably with a plate. Beware of free pins that tend to migrate.

Mid-third fractures

If little displacement is present conservative treatment with a sling will be sufficient. In cases of displacement >100% or > 2 cm of shortening, fixation is indicated. Flail chest, scapulothoracic dissociation, fractures menacing the integrity of the skin or open fractures are also indications for operative fixation. Activities such as professional cycling cannot tolerate unequal clavicular lengths and in these cases reconstruction is indicated.
Fixation may be accomplished with a 3.5 mm reconstruction or dynamic compression with or without locked screws. Nails of different types have been advocated and reported to be successful by many authors.
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Distal third fractures

In case of displacement > 100%, skin menace or open fracture fixation is indicated. Depending on the size of the distal fragment the surgical intervention can vary from simple excision, to figure of 8 wiring with pins, to heavy sutures to specific plates or hook plates. If the coracoclavicular ligaments are compromised (Neer type II fractures) coracoclavicular fixation (sutures or screws) may be indicated.
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Complications

Infections, nonunions or neurovascular compromise dominate the scene.
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Sternoclavicular dislocations

Anatomy

With relatively no osseous constraints, stability is provided by the anterior capsular ligament, the posterior capsular ligament, and a joint meniscus. The costoclavicular and interclavicular ligaments provide adjunct stability.

Antero-superior dislocation

Unstable and needs surgical intervention for stability. Usually reassurance and conservative treatment will suffice however.

Postero-inferior dislocation

This is potentially a life threatening situation. Symptoms are related to the posterior structures under compression (dyspnea, dysphagia, vascular compromise or thrombosis). CT is helpful to make the diagnosis. Reduction under anaesthesia with a bolster under the dorsal spine and simultaneously pulling the arm in extension while grabbing the clavicle end with a towel clip will usually reduce the clavicle that will stay stable.
Beware of fractures passing trough the proximal growth plate, which is the last to ossify at age 25.
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disruption to the sternoclavicular joint with the proposal of a new classification system. J Trauma. 2009;66(2):576-84.

Acromioclavicular dislocations

Usually a consequence of a fall on the tip of the shoulder in a young to middle-aged male athlete, the acromion is pushed downwards and the coraco- and acriomio-clavicular ligaments are damaged to varying degrees along with a displacement of the clavicle with respect to the shoulder girdle.
The patient presents with a deformity due to the antero-inferior position of the shoulder girdle.

Check for instability in the frontal and tranverse planes. Inspect the skin to rule out abrasions.
AP X-rays of the shoulder, Zanca views (10°-15° cephalic tilt) and axillary views are necessary and sufficient. An AP X-ray view of the shoulder girdle is a useful adjunct. Stress views are not necessary.
AC dislocations are classified according to Rockwood:
Type I: Strain without tear, Type II tearing of AC ligaments, Type III: Tearing of AC and CC ligaments (Trapezoid and conoid), Type IV: posterior displacement of the clavicle in relation to the acromion. Type V: More than 100% displacement with tearing of AC and CC ligaments and overlying trapezius muscle.
Surgery is usually recommended in types IV and V. Type III is controversial in frail patients in may be recommended. The techniques may involve coraco-clavicular screws, CC and AC heavy sutures or tapes or transarticular pinning.
Types I and II need conservative treatment.
In long standing cases the Weaver-Dunn procedure is recommended, with removal of 1 cm of the distal clavicle and using the coraco-acromial ligament as a substitute inserted into the hollowed out distal clavicle. Hook plates are used by some aurthors but will require reoperation for their removal.
-The Shoulder, Fourth Edition. Editors CA Rockwood, FA Matsen, MA Wirth, SB Lippitt. 2009, Philadelphia, Saunders Elsevier.
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Scapular fractures
Fractures of the scapula result from high energy trauma with 80 to 95% incidence of associated trauma 50% of which are thoracic trauma. Mortality is 10% to 15% principally due to associated thoracic and cranial injuries. Thorough clinical examination is mandatory and CT with 3D reconstruction is of great help in determining the exact extent of the fracture.

Scapulothoracic dissociation
This is the equivalent of an internal amputation entailing serious neurovascular damages. This injury is associated with a traumatic break or dislocation of the shoulder girdle (AC, clavicle, SC) and a lateral displacement of the scapula as seen on AP chest X-Ray. Consequences are dire and in many cases lead to loss of the upper extremity or death from major thoracic injury or massive haemorrage.
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Body Fractures
Most of these fractures may be treated conservatively, the scapula being well protected and surrounded by muscles. The most popular classification is the Ideberg classification.
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- Lantry JM, Roberts CS, Giannoudis PV. Operative treatment of scapular fractures: a systematic review. Injury. 2008;39(3):271-83..

Glenoid Fractures
Fractures of the glenoid surface and rim must be reduced and fixed if they are accompanied by instability or subluxation of the glenohumeral joint. If the humeral head does not appear centered in AP and axillary views and in CT cuts then the indication is absolute. When the joint remains centered, the indication for fixation becomes relative.
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Acromion and Spine Fractures

Displaced fractures of the acromion or the spine of the scapula need plate fixation or tension band fixation. Constant pull of the deltoid will displace the fragments and lead to a secondary impingement that may be difficult to treat.

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Glenohumeral dislocation

Introduction

Dislocation applies to a complete loss of contact between two joint surfaces. Subluxation implies partial loss of contact. Laxity is the result of a clinical examination showing more than "normal" passive motion or translation. Instability is a subjective sensation described by the patient that includes subluxation up to dislocation.

Glenohumeral instability is a spectrum that includes hyperlaxity and traumatic dislocation whether anterior or posterior or multidirectional.

Classification of the different types of instability include:

- Traumatic anterior dislocation: Accidental fall
- Traumatic posterior dislocation: Accidental fall
- Atraumatic instability due to capsular stretching because repeated "micro-trauma"
- Multidirectional instability due to capsular laxity

Pathoanatomy

Traumatic anterior instability

Generally accompanied by a tear of the capsulo-labral complex that sometimes includes osseous fragments off from the glenoid rim: The Bankart lesion.

Anterior capsular stretching.

In many cases a bony trough in the posterior-superior region of the head will be caused by impaction against the glenoid rim sometimes leading up to a fracture of the greater tuberosity: *The Hill-Sachs lesion*.

Traumatic anterior instability

The inferior glenohumeral ligament is the main restraint in abduction/external rotation and found to be torn or detached in all cases of traumatic dislocation.

Generally accompanied by detachment and stretching of the posterior capsulo-ligamentous complex, rarely with osseous lesions involving the glenoid rim: The reverse Bankart lesion.

Posterior capsular stretching.

Impaction of the anterior region of the head just medial to the lesser tuberosity leading up to a head-split fracture: The reverse Hill-Sachs lesion.

Dislocation and instability types

Anterior dislocation

Usually related to sports activities (soccer, skiing etc.) or falls.

Recurrence rates are high in patients below 20 yrs (up to 90%), between 20 and 40 yrs 60% recurrence rates, above 40 yrs 10%. These numbers vary depending on authors but trends remain.

Clinical examination is dominated by apprehension in abduction and external rotation.

Signs of generalized laxity are often present: Antero-posterior drawer, inferior sulcus sign, joint hyperlaxity (fingers, thumb, elbow).

In acute cases axillary nerve injury occurs in 5% of patients.

Imaging involves AP and axillary views. Arthro-CT scans delineate precisely bony morphology of fractures; Hill-Sachs lesions, glenoid brim fractures or rounding are well visualized. MRI may be helpful but bony lesions are poorly demonstrated.

Treatment for acute dislocations

AFTER diagnostic X-Rays: Reduction techniques include, after neurovascular testing, Stimson (Patient prone, arm hanging with 1 to 3 kg

weights attached to the wrist), Saha (slow elevation in the plane of the scapula), Kocher (Adduction in internal rot followed by abduction in ext rotation), Traction after intra-articular injection of lidocaïne or equivalent, Davos (Patient to cross his fingers around his flexed knee and with elbows extended is instructed to slowly bend backwards), Hippocrates technique (anesthetized, traction on the arm and with foot in the axilla which should be replaced by a towel) should only be performed when the non traumatic techniques have failed.
Postreduction treatment includes, after neurovascular testing, immobilisation in internal rotation or in an external rotation splint. (The rationale for the external rotation immobilisation is to force the Bankart lesion to stay fixed to the anterior glenoid rim pressured by the subscapularis). Immobilisation should be 2 to 4 weeks followed by strengthening exercises.

Treatment for recurrent dislocations

Surgical indications for stabilisation include one episode of dislocation too many, or severe apprehension.
Techniques include capsulorraphy, Bankart lesion refixation, bony augmentation if severe rounding or fracture of the rim.
Open or arthroscopic techniques are both suitable. Closed arthroscopic techniques are advocated in traumatic Bankart lesions, open techniques are recommended in cases of capsular stretching or large Hill-Sachs lesions. Recurrence rates range between 5% and 30% depending on technique used, strength of reconstruction and patient compliance.
Patients are immobilized from 3 to 6 weeks in internal rotation; rehabilitation emphasizes muscular strengthening in the first weeks followed by range of motion exercises. Patients are advised to avoid contact sports for a year following stabilisation.

Posterior dislocation

Fall on outstretched hand, seizures or electrical shocks are the main causes. AP and axillary X-rays for diagnosis. Relatively rare; less than 5% of all instabilities. Beware of the diagnosis: The cardinal sign is active and passive limitation of external rotation. On the AP X-ray, the joint space is not visible and the axillary is always diagnostic. In doubt a CT will solve the issue.

Treatment for acute dislocations

If a small i.e.less than 10% reverse Hill-Sachs is present, gentle traction will generally reduce the shoulder which should then be immobilized in an external rotation splint for three to 6 weeks with a rehabilitation programme to follow.
If a large Hill-Sachs lesion is present, reduction under anaesthesia may be necessary followed by the McLaughlin procedure where through an anterior deltopectoral incision the head is gently levered out and the subscapularis or the osteotomized lesser tuberosity is sutured or screwed into the bony defect. External rotation immobilisation 4 to 6 weeks followed by a rehabilitation programme.

Treatment for recurrent dislocations

If no major Hill-Sachs lesion is present a posterior approach with a cruciate capsulorraphy and fixation of the reverse Bankart lesion is performed. A bone graft from the spine of the scapula or the iliac crest may be necessary if a bony defect is present.
If a major Hill-Sachs lesion is present a McLaughlin procedure will be necessary and if insufficient an adjunct posterior procedure may be necessary.

Multidirectional dislocation

Young patients with laxity and instability in more than one direction, i.e. anterior and posterior or posterior and inferior or all three. Cardinal signs are hyperlaxity, sulcus sign and anterior and posterior drawer signs all causing discomfort or apprehension.
Standard X-rays, arthro-CT or MRI will delineate the existing lesions. Surgery is indicated only after one year of serious muscle strengthening physiotherapy and exercises.
The most commonly accepted operation is Neer's capsular shift which may be performed through an anterior deltopectoral approach but in certain cases may need an adjunct posterior approach. The axillary nerve must be protected during this demanding and complex intervention. 6 weeks of immobilisation in neutral (handshake) position is necessary follwed by a muscle strengthening programme.

Chronic dislocation
Usually seen in debilitated patients. The best option may be no treatment. In cases of chroni pain and discomfort shoulder fusion may be another option. Some authors advocate the reverse prosthesis but the danger of dislocation is great.

Recurrent dislocation in the elderly patient
Often these dislocations are associated with minor trauma. A massive rotator cuff tear is the usual cause. If repairable the supra and infra-spinatus lesions should be repaired. If not repairable the reverse prosthesis may be an option and if not fusion may have to be performed.

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Proximal humerus fractures

Introduction
Proximal humerus fractures constitute 5% of all fractures. High energy fractures occur in young males and low energy fractures in elderly females. They are intra-articular fractures and treatment modalities should attempt to reconstruct the anatomy so that function may be best restored. 80% of all these fractures need conservative treatment. Avascular necrosis, mal or non unions, stiffness and postoperative sepsis plague the treatment results.

Biomechanics
The quasi sphericity of the humeral head allows smooth articulation on the glenoid. The subacromial arch must be preserved; any bony fragments or overgrowth will lead to impingement inhibiting motion. The rotator cuff plays the roles of transmission belt, spacer and shock absorber. Translation of the humeral head is limited by the glenoid geometry, the labrum, the glenohumeral ligaments and the coaptation force of the cuff muscles. The deltoid muscle provides power in elevation and abduction, the rotator cuff centers the humeral head and provides power in external (infraspinatus) and internal rotation (subscapularis). The supraspinatus fine tunes practically all glenohumeral movements. The pectoral plays a role in adduction and internal rotation.
-The Shoulder, Fourth Edition. Editors CA Rockwood, FA Matsen, MA Wirth, SB Lippitt. 2009, Philadelphia, Saunders Elsevier

Anatomy
The humeral head is a half sphere with a diameter between 37 to 57 mm, inclined at 130°, retroverted at 30°. The axillary artery is divided into three segments by the pectoralis minor muscle. The first part is medial to the pectoralis minor muscle, the second part is deep to the pectoralis minor muscle and the third part lateral to the pectoralis minor has three branches: the subscapular artery (the circumflex scapular branch runs through the triangular space), the anterior humeral circumflex artery and the posterior humeral circumflex artery accompanies the axillary nerve and exits posteriorly through the quadrilateral space (medial: long head of triceps, lateral: humeral shaft, superior: teres minor, inferior: teres major). The blood supply of the humeral head is provided by the anterolateral ascending branch of the anterior circum-flex artery terminating into the arcuate artery in the humeral head, the rotator cuff arterial supply, the central metaphyseal artery and the posterior circumflex artery. Innervation of the deltoid and teres minor muscles arises from the axillary nerve along with a sensory compo-nent in the lateral shoulder. Innervation of supra and infraspinatus depends on the suprascapular nerve passing through the scapular notch giving off branches to the supraspinatus and then passing around the spinoglenoid notch to innervate the infraspinatus. The subscapularis is innervated by the subscapularis nerve, a direct branch off of the posterior trunk of the brachial plexus. The pectoralis muscle nerve stems off the medial trunk.
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Clinical Presentation

Deformity and functional impairment are the presenting signs and symptoms. The neurovascular status must be explored namely the status of the axillary nerve. In undisplaced fractures a tell-tale ecchymosis appearing two to three days after a fall will sign an underlying fracture. Diagnosis will be made with well-centered x-rays AP and axillary views. If operative treatment is entertained a CT with 3D reconstruction will give invaluable information. MRI may be occasionally useful for assessment of the rotator cuff or to ascertain the existence of a fracture. Excellent imaging is the only way to accurately classify the fracture and establish a prognosis as to the occurrence of avascular necrosis.

-The Shoulder, Fourth Edition. Editors CA Rockwood, FA Matsen, MA Wirth, SB Lippitt. 2009, Philadelphia, Saunders Elsevier

Classification of Proximal Humeral Fractures

Many classification schemes exist: Neer classification into two, three and four part fractures, a fracture is deemed displaced if there is more than 1 cm of displacement or 45° of angulation. The AO-OTA classification is based on the scheme of the overall AO classification. The "Lego" classification of Hertel is interesting because it allows to combine the different fracture patterns and the Duparc classification which has an anatomic and functional determinant. However although helpful, none of these classifications has perfect inter or intra-observer reliability.

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Conservative Treatment

Most fractures will not be greatly displaced; immobilisation for three to six weeks in a shoulder immobilizer or a Velpeau type bandage will be indicated. Rarely an abduction splint will be needed to hold the fracture pattern in an acceptable position. Appropriate analgesic medications should be prescribed and personal hygiene measures with removal of the Velpeau every five days should be organized in the first weeks. After 3 to 6 weeks depending on the fracture type gentle physiotherapeutic exercises, emphasising on isometric exercises should be instituted. The fracture will heal in 12 weeks.

Surgical Approaches

Delto-pectoral approach

The cephalic vein should if possible be preserved. The axillary nerve must be palpated in front of the subscapularis. If the long biceps tendon is not anatomically replaced a tenodesis is in order.

Trans-deltoid approach

The deltoid should not be split further than 5 cm distal to the acromion to protect the axillary nerve.

Posterior approach

A deltoid split will lead to the unfraspinatus which may have to be detached to access the capsule for arthrotomy. Rarely used approach in the trauma setting.

-The Shoulder, Fourth Edition. Editors CA Rockwood, FA Matsen, MA Wirth, SB Lippitt. 2009, Philadelphia, Saunders Elsevier

-AAOS Comprehensive Orthopaedic Review. Jay R. Lieberman, MD, Editor 2009 Rosemont, IL, American Academy of Orthopaedic Surgeons.

Operative techniques

Isolated greater tuberosity fractures

Displacement of more than 0,5 to 1cm warrants operative treatment. Usually a trans-deltoid approach with suture fixation, sometimes augmented by isolated screws or perhaps a plate in case of a large fragment.

Displaced lesser tuberosity fractures

Anatomic reduction and fixation with screws is warranted to preserve subscapularis function.

Two part displaced surgical neck fracture

Plating or IM nailing can be used successfully in this indication.

Three part fractures

In strong bone percutaneous pinning may be used although accurate reduction is best achieved with an open technique. Some authors favour locked nailing for these fractures. In weak bone a deltopectoral approach with plate fixation with or without fixed angle screws or an osteosuture technique will be indicated. The biceps if well aligned in the bicipital groove is a precious indicator as to reduction accuracy. It is wise to check the reduction before closure with an X-ray or an image intensifier.

Four part fractures

Prosthetic replacement respecting height, version and tuberosity fixation will be used in the elderly patient. In high demand young patients it is probably best to attempt plate osteosynthesis with angle stable screws. This is an acceptable solution only if an adequate anatomical reconstruction has been achieved. If not, a hemiarthroplasty with careful reconstruction of the tuberosities is an acceptable option.

Fracture-dislocations

Reduction must be obtained under anaesthesia so as not to displace a pre-existing humeral neck fracture. If there is doubt an open reduction should be done. Fixation will then depend on the fracture pattern. In very difficult situations it may be necessary to do a deltoid take-down to increase exposure. Careful neurovascular assessment must precede any surgical act and if necessary appropriate vascular imaging should be obtained.

Posterior dislocations

This may be a difficult to diagnosis often associated with seizures, although a fall on the outstretched hand can cause posterior dislocation. The hallmark is lack of external rotation passive or active. Plain x-rays must be scrutinized and if there is a doubt a CT scan is the best option. Active investigations should include neurological assessment to rule out intracranial tumours or other causes of seizures. If a large reverse Hill Sachs lesion is present or if a head splitting fracture is present the treatment may have to be surgical. The McLaughlin procedure is the insertion of the subscapularis tendon into the reverse Hill-Sachs lesion while the Neer modified approach osteotomizes the lesser tuberosity which is fixed with screws into the bed of the Hill-Sachs lesion. In all cases, whether the treatment is operative or conservative, post-reduction immobilisation is in external rotation often with the help of a splint.

-The Shoulder, Fourth Edition. Editors CA Rockwood, FA Matsen, MA Wirth, SB Lippitt. 2009, Philadelphia, Saunders Elsevier
-Hoffmeyer P. The operative management of displaced fractures of the proximal humerus. J Bone Joint Surg Br; 2002.84(4):469–480.
-Gerber C, Werner CM, Vienne P (2004) Internal fixation of complex fractures of the proximal humerus. J Bone Joint Surg Br; 86(6):848–855.
-Brems JJ (2002) Shoulder arthroplasty in the face of acute fracture: puzzle pieces. J Arthroplasty; 17(4 Suppl 1):32–35.

Humeral shaft fractures

Foreword

In the AO manual that covers all important fixation techniques the reader will fact pertinent facts related to the topic at hand: *AO Principles of Fracture Management. Second expanded edition, TP Rüedi, RE Buckley, CG Moran. Georg Thieme Verlag; 2 Har/Dvdr edition (2007).* For the latest in fracture fixation techniques the reader is also invited to visit the AO surgery reference site: *AO surgery reference: http://www.aofoundation.org.* Another most useful publication containing pertinent facts related to orthopaedics and musculoskeletal in general trauma is the *AAOS Comprehensive Orthopaedic Review. Jay R. Lieberman, MD, Editor 2009 Rosemont, IL, American Academy of Orthopaedic Surgeons. For surgical approaches the most useful reference is without doubt: Surgical Exposures in Orthopaedics: The Anatomic Approach. Hoppenfeld S, deBoer P, Buckley R. Lippincott Williams & Wilkins; Fourth Edition edition 2009.*

Introduction

Fractures of the humeral shaft represent 2-3% of fractures and are distributed in a bimodal mode. High energy fractures are typical of younger patients while low energy fractures are more commonly seen in the elderly osteoporotic individual. These fractures are the result of blunt trauma resulting from a fall and more rarely from gunshot wounds or war injuries. Sports are associated with these fractures such as hangglider inuries or result from arm wrestling. Pathologic fractures are also commonly seen arising from bony fragilisation resulting from metastases (8% of humeral fractures). All neoplastic diseases solid or haematological may cause metastatic disease. The neoplasms most frequently involved are those arising from: Breast, kidney, thyroid, lung, prostate or multiple myeloma. Chronic osteomyelitis either primary or associated with haemoglobinopathies may also cause associated fractures.

-Ekholm R, Adami J, Tidermark J, Hansson K, Törnkvist H, Ponzer S Fractures of the shaft of the humerus. An epidemiological study of 401 fractures. J Bone Joint Surg Br. 2006;88(11):1469-73.

-Sarahrudi K, Wolf H, Funovics P, Pajenda G, Hausmann JT, Vécsei V. Surgical treatment of pathological fractures of the shaft of the humerus. J Trauma. 2009;66(3):789-94.

-Frassica FJ, Frassica DA. Metastatic bone disease of the humerus. J Am Acad Orthop Surg. 2003;11(4):282-8.

Biomechanics

The main forces acting on the humerus are torsional.

Anatomy

The main anatomical feature is the medial to lateral posteriorly running spiral groove housing the radial nerve beginning at 20 cm medially from the distal articular surface and ending 14 cm proximal to the distal joint surface. The radial nerve is reported to be injured on average in 11.8% in fractures of the humeral shaft.

-Shao YC, Harwood P, Grotz MR, Limb D, Giannoudis PV. Radial nerve palsy associated with fractures of the shaft of the humerus: a systematic review. J Bone Joint Surg Br. 2005;87:1647–1652.

-AAOS Comprehensive Orthopaedic Review. Jay R. Lieberman, MD, Editor 2009 Rosemont, IL, American Academy of Orthopaedic Surgeons.

Classification of humeral shaft fractures

The AO classification is popular. It classifies the fracture patterns of the humeral shaft as type A (simple, transverse or spiral) type B (wedge with a butterfly fragment) and type C (segmental or comminuted fragments). Open fractures are classified according to Gustilo and Anderson: Type I inside-out (< 1 cm), Type II outside-in (> 1cm), Type III A (open, osseous coverage possible), type III B (open, necessitating a local or free flap), Type III C (Open fracture with vascular injury).

-AO Principles of Fracture Management. Second expanded edition
Thomas P Rüedi, Richard E Buckley, Christopher G Moran. Georg Thieme Verlag; 2 Har/Dvdr edition (2007).

-Gustilo RB, Mendoza RM, Williams DN. Problems in the management of type III (severe) open fractures. A new classification of type III fractures. J Trauma 1984, 24:742-746.

-Gustilo RB, Anderson J. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: Retrospective and prospective analyses. J Bone Joint Surg Am 1976;58:453-458.

Clinical presentation

A deformed extremity is present. Look for neurovascular injuries (radial nerve) carefully before any manipulation of the injured extremity. Plain X-rays including the shoulder and elbow are generally sufficient in acute traumatic cases. MRI, CT, Bone scintigraphy are useful in special situations such as chronic infection, metastatic or primary tumors.

Conservative treatment

Usually if conservative treatment is chosen the patient is first immobilised in a Velpeau type bandage and after two to three weeks when swelling has diminished a functional brace is applied. There exist no guidelines but many agree that planar angulations of 20° sagittally and 15° frontally, malrotations up to 15°, and shortening up to 3 cm are acceptable. According to Sarmiento the most common complication of conservative functional bracing is varus angulation:16%>10°-20°.

-Sarmiento A, Latta LL. Humeral diaphyseal fractures: functional bracing. Unfallchirurg. 2007;110(10):824-32.

-Sarmiento A, Zagorski JB, Zych GA: Functional bracing for the treatment of fractures of the humeral diaphysis. J Bone Joint Surg Am 2000;82:478-486.

Surgical Approaches

Antero-lateral approach

The radial nerve may be identified in the intermuscular groove between the brachialis and the brachioradialis. It is followed up into its entry into the groove. The brachialis is then split to reveal the entire length of the shaft if necessary.

-Mekhail AO, Checroun AJ, Ebraheim NA, Jackson WT, Yeasting RA.Extensile approach to the anterolateral surface of the humerus and the radial nerve. J Shoulder Elbow Surg. 1999;8(2):112-8.

Posterior approach

The radial nerve is identified running obliquely from medial to lateral under the heads of the triceps. The ulnar nerve runs along the medial border of the medial head of the triceps. This is not a suitable approach for proximal fractures because of the deltoid insertion.

-Zlotolow DA, Catalano LW 3rd, Barron OA, Glickel SZ. Surgical exposures of the humerus. J Am Acad Orthop Surg. 2006;14(13):754-65.

Operative treatment indications

The list is not exhaustive and includes the following: Open fractures, bilateral fractures, vascular injury, immediate radial nerve palsy, floating elbow, failure of closed treatment, pathologic fractures (bone metastases), brachial plexus injury, and obesity.

IM Nailing

Nailing is an advantageous minimally invasive technique that is suitable for unstable fractures. Control of rotation is achieved with locking bolts. Shoulder pain is common after anterograde nailing. Non-unions are more common with nailing than with plating.

-Anterograde

Care must be taken with an adequate point of entry; most nails enter through the cartilaginous surface of the head thus minimizing injury to the rotator cuff.

-Retrograde

Entry point must be well above the olecranon fossa to avoid fragilizing the distal humerus. This is not suited for distal fractures.

Plating

Using a lateral or a posterior approach, plates suitable to the anatomy (broad plates in a large bone, narrow plates in a small bone) should be used. Attempts at minimally invasive approaches with incisions proximally and distally (radial nerve) allowing closed plate insertions are being developed. Locked screws may be useful in osteoporotic bone. Union rates of more than 94% are achieved with plating.

External fixation

Indicated in polytrauma (Staged in damage control orthopaedics), open fractures or situations were formal osteosynthesis with nailing or plating is not possible. Open approaches are recommended to avoid injuring nerves. If the elbow must be spanned it is preferable to insert the pins in the ulna.

-Bhandari M, Devereaux PJ, McKee MD: Compression plating versus intramedullary nailing of humeral shaft fractures—A meta-analysis. Acta Orthop 2006;77:279-284.
-Popescu D, Fernandez-Valencia JA, Rios M, Cuñé J, Domingo A, Prat S. Internal fixation of proximal humerus fractures using the T2-proximal humeral nail. Arch Orthop Trauma Surg. 2008
-Park JY, Pandher DS, Chun JY,et al. Antegrade humeral nailing through the rotator cuff interval: a new entry portal. J Orthop Trauma. 2008;22(6):419-25.

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