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Osteosynthesis of Major Fractures in Polytrauma

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The treatment of multiple trauma patients is subdivided into pre-hospital and hospital periods. The hospital period is divided according to diagnostic and therapeutic measures into acute, primary, secondary, and tertiary periods. In the acute period, all life-threatening injuries, e.g., severe abdominal bleeding, are treated. In the primary period, visceral injuries such as bowel rupture and fractures with vessel injuries, open fractures, open joints, severe compartment syndromes, and closed femoral fractures require surgery. In the secondary period, prolonged joint reconstructions, closed fractures of the forearm, and partially reconstructive surgery are performed. In the tertiary period, reconstructive surgery is done (e.g., cancellous bone grafts). Using this regimen in multiple trauma patients, we not only obtain restoration of vital function, but also good restoration of the extremities is achieved.

Blood loss and tissue trauma due to direct organ injuries are the cause of traumatic shock in multiple trauma patients. This results in inadequate capillary perfusion and increased capillary permeability, which can later lead to respiratory insufficiency, multiple organ failure, and sepsis.

The initial priority in multiple trauma patients is that of injuries to the body cavities, but after days or even hours injuries of the extremities can also be quite dangerous to these patients.

Operations on the extremities are often associated with inadequate blood volume replacement, resulting in worsening of the traumatic shock. Since the trauma of the operation occurs at the same time, it is often wrongly suspected as the cause. On the other hand, operative fracture treatment can influence the post-traumatic outcome in 3 ways. First, patient care can be improved by frequently changing the patient's position, thereby avoiding hypostasis and the risk of developing pneumonia with its consequent associated ventilator dependence (ARDS) and protein catabolic states. Second, stable fracture fixation can decrease pain. Pain is a cause of the protein catabolic state and absolute immobilization of the muscles is a cause of pulmonary thrombembolism. Finally, stable fixation of fractures by osteosynthesis can decrease muscle and soft tissue trauma. Movement in conservative fracture treatment may lead to muscle trauma and hemorrhage with the liberation of shock-specific mediators, which can further increase the difficulty in perfusing the tissues and the risk of developing respiratory insufficiency.

There are 2 main aims in the treatment of multiple trauma patients: (a) the protection of the vital function of the heart, lung, liver, kidney, and brain with avoidance of sepsis; and (b) restoration of the patient to normal activity by maintaining optimal function of the brain and loco-motor system. A considerable degree of organized activity must be achieved if these major aims are to be obtained. This requires excellent organization, adequate facilities and personnel for the optimal treatment of all injuries, and optimal intensive care.

The organization for multiple trauma patients should include the standardized use of diagnostic measures and methods of treatment. The therapeutic chain is only as strong as its weakest link, and therefore only in this way can rapid treatment of multiple trauma patients be possible. In our unit, there are 8 personnel on call for the emergency treatment of each severely injured patient. When a call is received, 8 staff members go immediately to the resuscitation room and prepare for the patient's resuscitation. The staff consists of an anesthesiologist, a nurse anesthetist, 2 trauma nurses, 3 trauma

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surgeons, and the senior trauma registrar. The latter is in charge and is responsible for every trauma patient the team receives, from the start to the completion of the treatment protocol. It is important that each person in the team knows his or her exact function so that a chaotic situation is avoided when a multiple trauma patient is admitted.

The adequate treatment of all multiple trauma patients is only possible in those hospitals where optimal treatment facilities are available for all types of injuries. In other words, these patients can only be treated adequately in certain hospitals, as is the case for open cardiac surgery. Only initial measures can be undertaken in a hospital that is not properly equipped. The facility postulations mean that diagnostic tools such as the computed tomography (CT) scan, angiography, etc., are available. The same is true for personnel postulations: neurosurgeons, abdominal surgeons, thoracic surgeons, urologists, and otolologists must be on call 24 hours a day.

Intensive care postulations must also be made. This means that adequate monitoring and ventilation systems must be available, as must, most important of all, a doctor experienced in intensive care treatment of multiple trauma patients.

Periods of Treatment

For the purpose of better organization, the treatment of multiple patients is divided into 2 main periods, pre-hospital and hospital (Table 1).

Table 1.

Polytrauma Management	
Prehospital Period	Hospital Period
Contact/Alarm Period	Acute Period
↓	↓
Resuscitation Period	Primary Period
↓	↓
Salvage Period	Secondary Period
↓	↓
Transportation Period	Tertiary Period

Pre-hospital Period

The pre-hospital period is subdivided into resuscitation, salvage, and transportation periods. Initially, early treatment of shock and the time factors involved are as important as the main support [1]. In the Federal Republic of Germany, there exists an almost perfectly organized rescue system utilizing helicopters and emergency ambulances, all staffed with trained personnel. The entire Federal Republic is covered by rescue helicopters in the rural districts and by emergency ambulances in the cities. Using this system, 80% of our 820 severely injured patients and 59% of our 678 open fracture patients were treated by our residents at the scene in an average time of 21 minutes following the injury, and then transferred to our hospital by helicopter or emergency ambulance. The infection rate for open fractures was 3.5% in those patients transported to hospital by helicopter as compared to 12.2% in those transported to hospital by ambulance and 1 in 5 admitted from other hospitals. Of the 116 patients who had a sterile dressing in place from the scene of the accident to the operating theater, only 4.3% developed infection as compared to 18.2% in the other group.

In a consecutive series of multiple trauma patients with an average of 7 severe injuries who were treated at the scene within 22 minutes of the accident, the fatality rate was 39%. In another group who had on average 5 severe injuries and who were initially treated at another hospital and arrived at our hospital some hours later, the fatality rate was 50%. In our unit between 1972 and June 1, 1982, there were 23,603 rescue missions by means of helicopter and emergency ambulance. Of these patients, 79.1% received intravenous infusions, were intubated or had fractures splinted at the scene of the accident. The rate of successful primary resuscitation at the scene of the accident was 28%. One-quarter of these patients were ultimately discharged in good condition.

Hospital Period

The hospital period is subdivided into acute, primary, secondary, and tertiary periods. During each period, certain diagnostic, therapeutic, and operative procedures must be performed simultaneously.

Acute period. The aim of the acute period is to diagnose life-threatening situations and treat them adequately. The blood volume deficit must be corrected according to blood pressure, pulse rate, and urine output. The measures used in the acute diagnostic period are those that aid in the recognition of life-threatening injuries. These include blood pressure, pulse rate, ventilation rate, neurologic status (according to the Glasgow Coma Scale [2, 3]), urine examination for hematuria, abdominal lavage, and x-rays of the thorax.

Therapy during the acute period includes blood volume being replaced aggressively using as many intravenous lines as necessary. We recommend venesection of the great saphenous vein at the

medial malleolus in multiple trauma patients. In patients with respiratory failure or progressive respiratory insufficiency, immediate intubation and mechanical ventilation are necessary. Fractures are splinted and dislocations reduced.

Acute surgery is performed if blood comes back immediately after the insertion of the lavage catheter. We see this as an indication for immediate laparotomy with no further diagnostic measures. In cases of severe head injury, confirmed by CT scan, operative treatment is performed. Hematomas in the skull, thorax, and abdomen all have the same priority (Table 2). Which hematoma should be operated on first depends upon its seriousness. Therefore, we have no absolute priorities. In multiple trauma patients with severe brain injury, the mainstay of treatment is correction of blood volume deficit. This was shown by Pitts [4], who found 90% of patients with severe brain injury and hypovolemia died, while 50% of patients with comparably severe brain injury without hypovolemia survived (Fig. 1).

Primary period. Following the acute period is the primary period. During this period, further diagnostic procedures are determined by the types of injuries the patient has. If vessel damage is suspected, angiography is performed; and with hematuria, an intravenous urogram and arteriography may be necessary. Following this, a radiological examination of the injured areas of the skeleton, including adjacent joints, is made. Hemodynamic monitoring is improved during this period by insertion of a Swan-Ganz catheter. Based on the values of pulmonary artery pressure, pulmonary wedge, and cardiac output, accurate volume replacement can be performed and drugs administered as required. Standard tests include arterial blood gases, hematocrit, hemoglobin, leucocyte count, clotting factors, electrolytes, transaminases, amylases, and blood glucose.

The operative treatment during this period deals with bowel ruptures, renal ruptures, and bladder and diaphragm injuries. There is no doubt that fractures in polytraumatized patients demand a generous indication for operative fracture treatment. In the primary period, all limb-preserving surgical approaches have priority (Table 3): injuries of major vessels, open joints, open fractures, and severe compartment syndromes. Generally, with these injuries we stabilize the accompanying fracture. The principle one should always strive for is stable osteosynthesis, thus making it possible to treat the patient with polytrauma functionally without plaster or traction (Figs. 2, 3).

The major prognostic determinants of limb function are the time and degree of hypoperfusion to tissues. In sudden and complete ischemia, there is a functional deficit of muscle tissue after 2–4 hours, irreversible after 4–6 hours [5, 6]. Damage to nervous tissue occurs more rapidly. After 30 minutes, there are functional deficits that are totally irreversible after 12–24 hours of complete ischemia [7, 8]. Fuhrmann and Chrismon [9] showed that severe damage occurs to the capillary membranes after 3 hours of ischemia. Based on the resulting increase in permeability, post-ischemic tissue swelling was found to be between 30 and 60%. Therefore, in the differential diagnosis of inadequate peripheral perfusion, it is important to differentiate between vessel injuries and compartment syndromes. In the multiple trauma patient with severely diminished arterial venous pressure differences, this leads to a compartment syndrome due to increased intrafascial pressures. Therefore, in these patients compartment syndromes that would have been reversible in normovolemic patients can lead to irreversible damage [10]. Diagnosis of the compartment syndrome requires direct tissue pressure measurement, clinical examination, and Doppler sonogram to identify peripheral pulses. We recommend decompression of the compartment before reconstruction of the injured vessels and fracture fixation.

A follow-up study on 103 compartment syndromes treated in our department showed 44% to occur in multiple trauma patients. One-third of these patients developed late sequelae based on delayed decompression. This high percentage emphasizes the danger of the compartment syndrome in multiple trauma patients [11].

Open fractures are also an indication for operation in the primary period, and are dealt with in detail elsewhere in this symposium. In a consecutive series of 678 open fractures, we saw an infection rate of 5.6% [12]. We recommend antibiotics for 48 hours for all open fractures. In a randomized prospective study in which patients were treated with (n = 111) and without (n = 88) antibiotics, we had an osseous infection rate of 2.7% with and 5.8% without antibiotics. In open joint fractures, closure and debridement of the wound and joint are necessary [13]. It is also important to perform operative stabilization at the same time so long as major dissection is not required. Soft tissue healing can be further improved by temporarily transfixing the

Table 2.

Surgery in Acute Period
1. Severe internal bleeding (intracranial, intrathoracic, intraabdominal)
2. Uncontrollable external bleeding

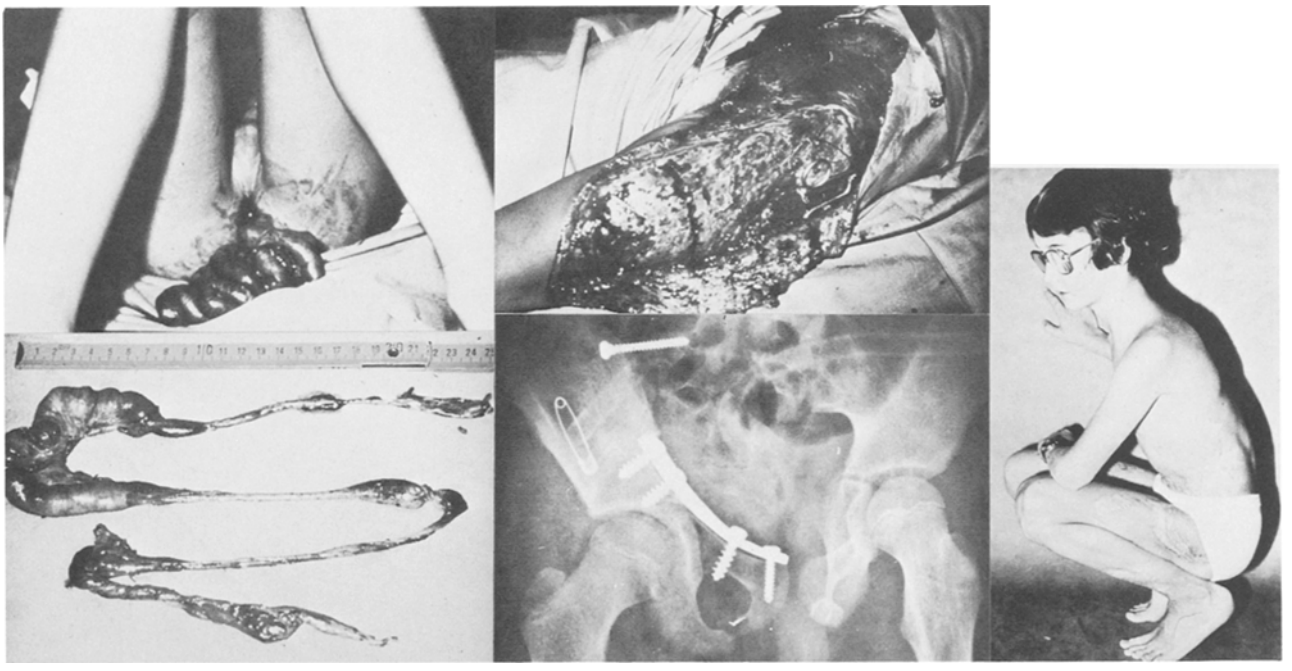

Fig. 1. A 10-year-old child was run over by a tank. The pelvis was crushed: open pelvic fracture, the intestinal prolapse through the anus, degloving injury on the thigh, rupture of 3 major pelvic vessels, and severe shock. Immediate life-saving operation, repair of vessel, resection of the bowel, and plate fixation of the pelvis. Functional result.

joints with external fixators. In all, very good treatment of the soft tissues without using a cast is possible.

In addition to osteosynthesis of open fractures, closed fractures of the femoral shaft should also be treated in the primary period. In patients with multiple injuries, femoral fractures cannot be sufficiently immobilized by traction. This is, therefore, a good indication for operative fixation to be undertaken as soon as possible. Any unnecessary delay increases the risk of infection, namely, pulmonary infections during artificial ventilation, nosocomial infections in the intensive care unit, and infections that result because the patients have a reduced immune response. A stable hemodynamic, respiratory, and coagulatory status is a prerequisite to operation. The following requirements must be met before surgery is undertaken:

1. Systolic blood pressure greater than 100 mm Hg
2. Heart rate less than 100 b.p.m.
3. Central venous pressure greater than 5 cm H_2O
4. Thrombocytes in excess of 100,000
5. Hematocrit greater than 25%
6. Arterial oxygen tension greater than 70 mm Hg

Due to the importance of femoral fractures, a great deal of consideration is required in multiple trauma patients. There is a much higher risk of respiratory complications such as atelectasis, during surgery, due to the patient's position on the traction table during closed intramedullary nailing. In addition, good positioning on the traction table is often impossible because of other injuries. For these reasons, we prefer plate osteosynthesis in fractures of the proximal and distal parts of the shaft of the femur and in second or third degree open femoral fractures. In closed femur fractures of the mid-shaft, we prefer intramedullary nailing with fixation of the larger fragments by cerclage wires. Using this method, early weight-bearing is possible and the risk of devitalization of the bony fragments and, thus, the risk of delayed union or non-union is minimal. In comminuted closed femur fractures, the fracture fragments are not touched but are bridged by a plate and extensive homografts are applied. Delayed autografting can be performed 2 or 3 weeks later with no risk to the patient. Ipsilateral fractures of the femoral neck and femur shaft are common injuries. In these cases, our standard procedure is

Table 3.

Surgery in Primary Period
1. Visceral injuries (bowel, bladder, diaphragm)
2. Open brain injuries
3. Progressive compression of spinal cord
4. Eye and facial trauma
5. Peripheral injuries
a) major vessel injuries
b) severe compartment syndromes
c) open joints
d) open fractures
e) closed femoral and pelvic fractures

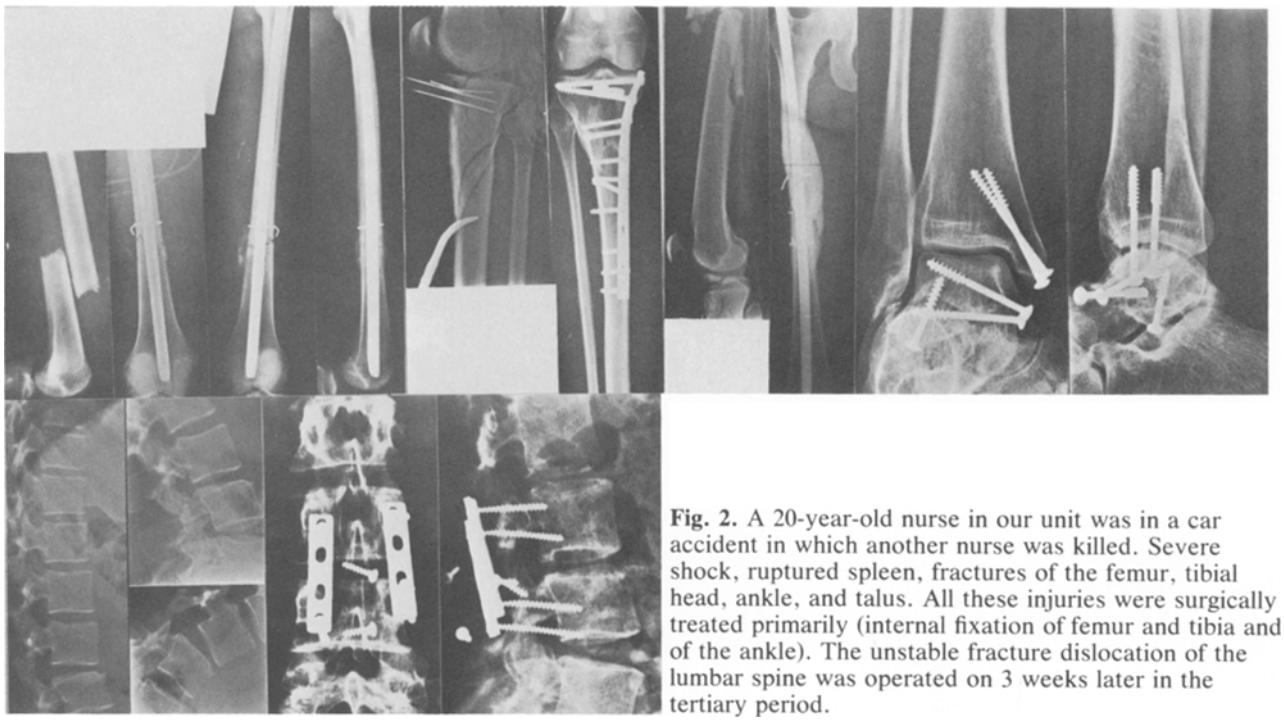

Fig. 2. A 20-year-old nurse in our unit was in a car accident in which another nurse was killed. Severe shock, ruptured spleen, fractures of the femur, tibial head, ankle, and talus. All these injuries were surgically treated primarily (internal fixation of femur and tibia and of the ankle). The unstable fracture dislocation of the lumbar spine was operated on 3 weeks later in the tertiary period.

that of intramedullary nailing of the diaphyseal fractures, combined with screw fixation of the proximal fracture.

With atypical fractures of the femoral neck, screw fixation is a very rigid form of internal fixation and the IM-nailing can be done as a closed or open procedure, as we did in 31 cases.

Between 1971 and 1980, we treated 503 fractures of the femoral shaft; 38.9% of these were in multiple trauma patients. In multiple trauma patients, 51.5% were treated on the day of the accident while 82.8% of patients with isolated fractures were treated on the day of the accident. Between the second and seventh day, we treated 18.9% of multiple trauma patients with fractures of the femoral shaft and only 10.3% of patients with isolated fractures. Of the multiple trauma patients with fractures of the femoral shaft, 16.9% were operated upon between the eighth and fourteenth days. Forty-eight percent were treated by plate and 52% by IM-nailing.

Pelvic fractures fall into a special group in multiple trauma patients, especially dislocations and vertical fractures involving the dorsal and ventral parts of the pelvis (Fig. 4). According to Schweiberer and Scheib [14], about 60% of all multiple trauma patients have a combination of fractures that includes fractures of the pelvis. In our own series of severely polytraumatized patients, 39.5% had severe pelvic fractures. Severe pelvic compression fractures in these patients are a special problem [15]. Angiography done via the axillary artery is of great diagnostic and therapeutic value in these cases. In patients with massive bleeding, we recommend immediate laparotomy with clamping of the aorta below the renal arteries. When the abdomen is open, angiography under controlled conditions using x-ray intensifier can be carried out and the damaged blood vessels repaired. In a series of 42 patients, Riska [16] found the most severely injured vessels were the inferior and superior gluteal arteries, the obturator artery, and the pudendal artery. Out of these 42 patients, 40 received more than 40 units of blood. Flemming and Bowen [17] had very good results with selective repair of vessels during the Vietnam War. In certain cases angiographic occlusion or embolization using catheters or clots of the patient's own blood was possible [18–20]. In severe pelvic fractures, operative fracture treatment is necessary for several reasons. First, there is less initial bleeding and long-term oozing from the blood vessels when the pelvis is reduced. Second, an exact reduction of the dorsal part of the pelvis can reduce the long-term sequelae [21].

Therefore, we recommend open reduction and internal fixation by plate and screw fixation. These methods of osteosynthesis are biomechanically more stable than external fixation and are associated with statistically better results. The operation itself is also easier and more rapidly performed. The ruptured symphysis is stabilized by a 4-hole plate, the dorsal vertical fracture or dislocation of the sacroiliac joint is fixed with plate and screws. If there are any contraindications to osteosynthesis in the primary period, then it is necessary to proceed

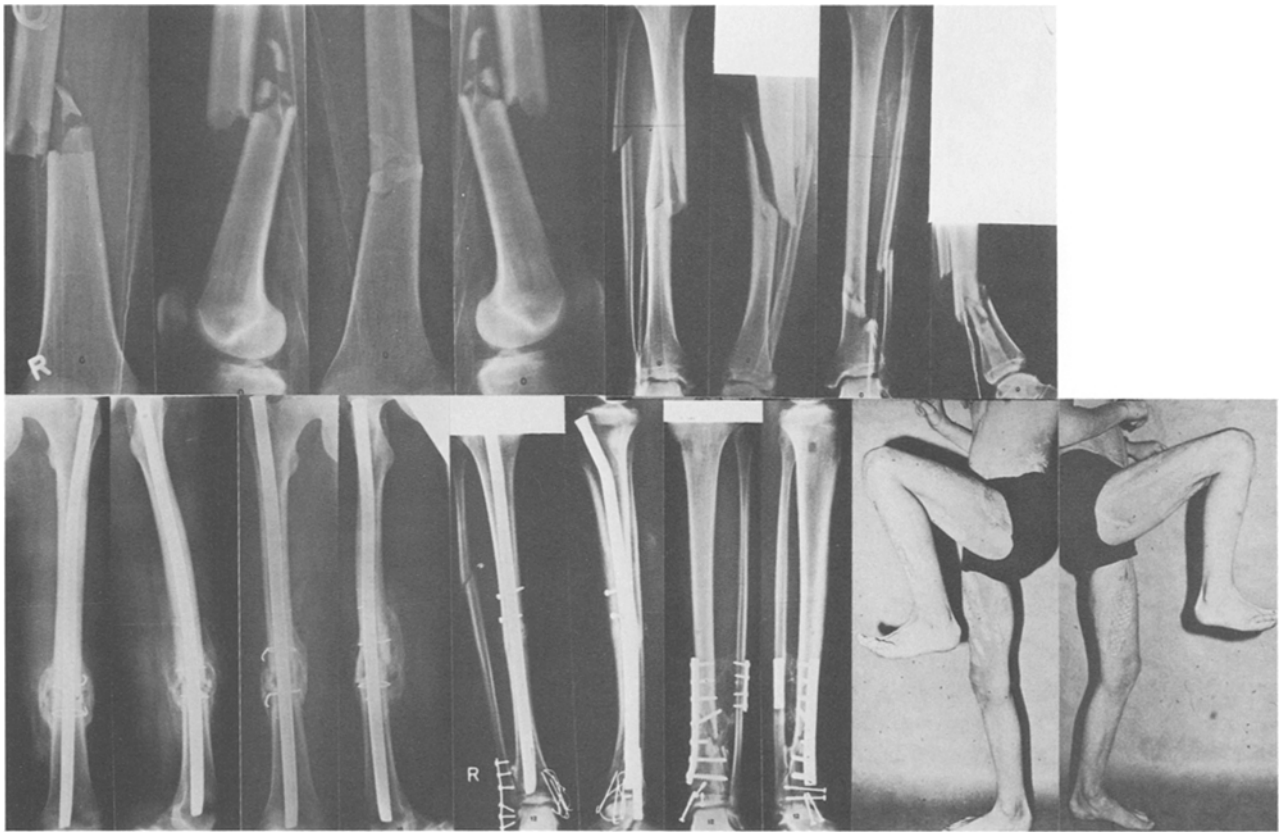

Fig. 3. A 22-year-old policeman was involved in a head-on crash with another car. The emergency treatment at the scene and the transportation were done by our helicopter rescue team. He had a total of 19 fractures, including fracture of the base of the skull, grade II open fractures of both femurs, grade II open fractures of both tibiae, ankle fractures both sides, distal forearm fracture both sides, and fracture of metacarpus and metatarsus. Sixty-four minutes after admission (primary operation period) the following were performed: debridement of all open fractures, reduction of the forearm fractures, and casting in plaster (duration, 110 min). Because of continuous stable condition, internal fixation of the right leg (IM-nailing of femur and tibia, ORIF of the ankle fracture dislocation) was completed. At the end of this procedure, the hemodynamic status was worsening a bit, therefore traction and plaster was applied on the left leg. The patient came in the ICU 10 hours after the accident. After an interval of 13 hours (second operation period), the fractures of the left limb were stabilized. At no time was the patient's life in danger. At the third operation period on the seventh day, ORIF of the fractures of the upper extremities and secondary wound closure of all open fractures was performed. Fracture healing after 12 weeks, back to work 18 weeks after injury.

with conservative fracture treatment until the physiologic situation can be improved. This becomes necessary when the condition of the patient deteriorates and operative fracture treatment is not possible.

Osteosynthesis of closed fractures of the upper extremity is less urgent and should be done only if the patient is in very stable condition. Besides Monteggia and Galeazzi fractures, the distal radius and metacarpal fractures can easily be treated by closed reduction and percutaneous pinning.

Secondary period. The start of the secondary period is determined when the hemodynamic and respiratory status of the patient have been stabilized, generally after 48–72 hours. During this period, hemodynamic monitoring in severely injured patients should be undertaken using a Swan-Ganz catheter. Monitored control of respiration is also necessary.

Depending upon the injuries, the patient may still be on artificial ventilation at this stage. During this period, fractures of the femur and serial fractures of the upper and lower extremities that have not been operated on in the primary period are now treated surgically. Surgery of severe intra-articular fractures requiring prolonged operation time should be done during this period (Table 4).

There exists some controversy concerning the operative treatment of fractures of the shaft of the humerus [22–24]. We prefer conservative treatment of fractures of the shaft of the humerus in contrast to some other authors [22, 25]. In a series of 69 multiple trauma patients with fractures of the shaft

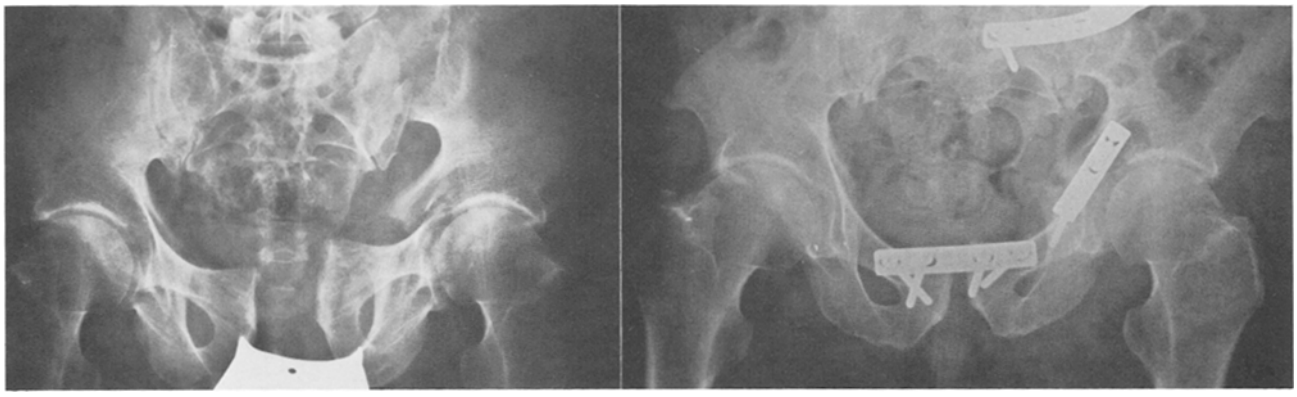

Fig. 4. Severe pelvic fracture (primary operation period): stabilizing of the symphysis and sacroiliac joint; (secondary operation period) osteosynthesis of the acetabulum.

of the humerus, 42 received conservative treatment and 27 operative stabilization. In this series, 46 were closed fractures and 23 open fractures. In a consecutive series of 159 fractures of the humeral diaphysis between 1973 and 1979, only 37 (23.2%) were treated surgically because of local concomitant injuries which prevented use of gravity traction by hanging cast or cuff and collar. The results included one case of infection, 2 cases of instability, and no postoperative radial nerve paralysis.

We recommend conservative treatment for 4 reasons:

1. Operative stabilization of the femur permits the patient to sit up, which allows use of gravity traction.
2. The fracture of the humeral shaft is a very benign type of fracture.
3. Fracture healing occurs in severely multiple trauma patients even without plaster fixation.
4. Operative treatment has a high incidence of complications.

In a multicenter trial involving 225 cases of osteosynthesis of the humeral shaft, the complication rate was 27.9% [25]; the rate of superficial infection, 4.4%; of osteomyelitis, 4.9%; of instability, 2.2%; of non-union, 6.6%; and of radial nerve palsy, 9.8%.

If the condition of the patient is unstable in the primary period, operative treatment of forearm fractures should be performed in the secondary period. This is the best time to obtain stable osteosynthesis. The disadvantage of postoperative plaster fixation was shown in a follow-up study of 664 forearm shaft fractures. In 25% of the patients who had plaster fixation for more than 3 weeks, the results were only fair [26]. Monteggia fractures are of special interest because of the concomitant luxation of the radio-humeral joint, which is often not reduced because of the associated shortening of the ulna. A follow-up study of 41 Monteggia fractures indicated that the operation time had a strong influence on the results. Fourteen of 18 patients treated by primary stable fixation had a very good or good result, but only 11 of the 23 who had a delayed operation had the same results.

Table 4.

Surgery in Secondary Period
1. Prolonged joint reconstructions (acetabulum)
2. Closed fractures of the forearm
3. Secondary wound closure bone grafting

Tertiary period. Following the secondary period, after approximately 6–7 days, is the tertiary period, which is determined by 2 events, septic complications and rehabilitation of the patient. We found the development of sepsis could be predicted by 2 parameters: (a) Bilirubin levels in patients who later developed sepsis increased more from 7 days than in those patients who did not develop septic complications. (b) Extravascular lung water was initially much greater in patients who later developed sepsis. Therefore, the main aim in this period is to eliminate septic foci in order to prevent septic complications.

If necessary during this period, the patients remain on mechanical ventilators and intensive monitoring. This is important, as the respiratory situation can deteriorate considerably because of increased capillary permeability.

If there are no septic complications, the main aim of the tertiary period is to mobilize the patient. During this time, only secondary reconstructive surgery should be carried out (e.g., secondary cancellous bone grafts and coverage of soft tissues).

Résumé

Le traitement des polytraumatisés subdivise en 2 étapes: avant l'hospitalisation et lors de l'hospitali-

sation. L'étape initiale d'hospitalisation est elle-même subdivisée en fonction du diagnostic et du traitement en 4 périodes: aiguë, immédiate, secondaire, tardive. Du cours de la première période les blessures mettant la vie en jeu sont traitées ainsi en est-il des lésions abdominales hémmoragiques. Lors de la deuxième période est pris en considération le traitement des ruptures intestinales, des fractures avec lésions vasculaires associées des fractures ouvertes, des fractures articulaires ouvertes, des fractures du fémur. Le traitement secondaire s'applique aux fractures articulaires fermés, aux fractures fermés de l'avant bras. Le traitement tardif répond à la chirurgie reconstructive (griffe osseuse retardée).

En se pliant a ces règles, chez le polytraumatisé, il est non seulement possible de sauver le blessé dont la vie est menacée mais aussi d'aboutir à de bons résultats fonctionnels.

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