Case Report

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Damage Control Resuscitation in a 12-Year Old Girl with Severe Thoraco--Abdominal Polytrauma

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Abstract

Introduction: A 12-year old girl experienced severe polytrauma after falling from a height of 20 m (ISS: 48). The girl was transported by helicopter using a "scoop-and-run" strategy. Ringer`s solution (500 mL) and tranexamic acid (500 mg) were administered. Intravenous administration of crystalloid solution was minimized, and blood and blood products were administered.

Case report: The child was intubated in the emergency room, and the tension pneumothorax was drained. The following findings were recorded: Serum lactate: 10.0 mmol/L, Base excess: -13.4 mmol/L, pH: 6.96, Hb: 100 g/L, INR: 1.65, Core Temperature: 35.9°C. Respiration rate before Intubation: 40/min, Pulse rate: 140/min, Blood Pressure: 85/46 mmHg, Glasgow Coma Scale: 6.

The CT scan revealed liver laceration, ruptured pancreatic tail, ruptured spleen, rupture of the right kidney, bilateral hemopneumothorax, a small subdural hematoma, intimal tear of the right carotid artery, central dislocation of the left hip joint, and a fracture of the humerus. Due to the presence of the "lethal triad" (acidosis, hypothermia, and coagulopathy), we used the damage control resuscitation (DCR) strategy, refraining from surgery within the first 24h. We induced permissive hypotension and stabilized the cardiopulmonary situation at the pediatric intensive care unit (PICU). After 24h, we reduced the dislocated hip fracture and stabilized the fracture of the humerus without reduction. Eight days later, the fractures were treated with open reduction and internal fixation. Hepatic bile duct injury was treated with stent insertion guided by endoscopic retrograde cholangiography (ERCG). The child survived, and only minor cerebral alterations were noted at follow-up.

Conclusion: DCR strategy offers a rewarding treatment option in children who sustained severe polytrauma. Broad application of this strategy in children necessitates further studies.

Keywords: Multiple trauma; Child; Damage control resuscitation; Thoracic trauma; Liver injury; Hip dislocation

Introduction

Despite modern treatment strategies for injuries and hypovolemic shock, thoraco-abdominal multiple trauma in children bears a high risk of complications and even mortality. The concept of damage control surgery (DCS) has been described by Rotondo et al. [1]. DCR is a new management strategy applied in children who suffered severe trauma, and no guidelines for children have been established as yet. The primary goal of trauma resuscitation is to prevent acidosis, coagulopathy, and hypothermia [2]. Children with multiple injuries admitted to an A&E resuscitation room are examined and managed according to ATLS- and PALS-guidelines [2].

So far, only few hospitals worldwide have implemented guidelines for multiple transfusions in children [3]. However, there is growing evidence that applying DCR and DCS strategies may improve the outcome in children suffering from life-threatening injuries.

In short, DCR in children who suffered multiple injuries focusses on the optimal management of the hypovolemic shock situation by restricting crystalloid fluid administration mainly to the pre-hospital transport phase [4,5]. In DCR, only small volumes of fluid are administered before surgery thus conveying an overall survival benefit for patients who will have to undergo urgent laparotomy [4]. This strategy increases arterial blood pressure in the initial phase of resuscitation only in the case of concomitant head injury which necessitates higher blood pressures to increase cerebral perfusion pressure (=arterial blood pressure minus intracranial pressure).

When cerebral perfusion pressure is assumed normal, a state of permissive hypotension is maintained to reduce the risk of freeing coagulated blood clots from spontaneously sealed injury sites [4]. DCR focusses on the efficient control of bleeding injuries and involves the administration of blood and blood products, thereby improving blood coagulation parameters while avoiding hypothermia. DCR reduces the mortality in patients with severe haemorrhage [4]. Close monitoring of blood coagulation parameters is required to achieve efficient hemostasis, preferably by a point-of-care blood coagulation analyzing system and the close collaboration with a blood bank and hemostaseology laboratory.

Compared to the standard resuscitation strategy where patients receive 2000 mL of crystalloid fluid and additional fluids as required, the controlled resuscitation strategy involving only small volumes of intravenous (i.v.) crystalloid fluid to maintain systolic blood pressure >70 mmHg results in reduced 24 h mortality in hypotensive adults suffering from blunt trauma [6]. The current guideline for resuscitation of trauma patients proposed by the American College of Surgeons' Advanced Trauma Life Support Course recommends initiating resuscitation of trauma patients with 1 L to 2 L of crystalloid fluids [7]. Initial examination of the injured child with adequate respiration and hemodynamic stability begins with the primary and secondary survey [8]. However, currently applied advanced trauma life support interventions go against the principles of DCR [4].

Diagnostic procedures are undertaken in a highly efficient way, and multislice CT scanners are used when focused assessment sonography for trauma (FAST) has ruled out massive intra-abdominal or intrathoracic bleeding or pericardial tamponade. We graded the severity of abdominal solid-organ injuries according to the American Association for the Surgery of Trauma Organ Injury Scale (AAST) guidelines [9,10]. Pneumothorax is excluded by clinical investigation, and this must not be overlooked during resuscitation as it may rapidly cause progressive deterioration of pulmonary function and the development of hypoxia, resulting in acidosis and further impairment of blood coagulation.

After the initial phase of DCR, non-operative treatment is preferred over operative management. Only limited and efficient surgical interventions to control bleeding areas and reduce contamination are undertaken during DCS. After DCR or DCS, the child is transferred to an appropriate PICU for further management. After hemodynamic stabilization and rewarming of the child, a second-look operation or other surgical interventions are conducted if necessary.

Today, the majority of orthopedic trauma surgeons recognize the influence of timing of fracture stabilization in adult polytrauma patients. However, few studies investigated the importance of timing of fracture fixation in children with multiple trauma [11]. Moreover, medical education of most physicians, nurses, and other members of the hospital staff does not include training in damage control strategies. This represents a dangerous situation for children involved in severe accidents. This case report aims to spread the knowledge about DCR strategies among accident and emergency caregivers and to improve the equipment of A&E rooms to allow for more efficient treatment of children suffering from life-threatening injuries and hemorrhagic shock.

We obtained written informed consent from the patient and her legal guardian to publish this case report.

Case Report

A 12-year old girl (bodyweight 43 kg) fell from a medieval castle wall into a forest in a 20 m free fall when she lost her balance during climbing (Figure 1).

Figure 1: Site of incident. The child fell from a height of 20m when climbing a rock.

She was found lying on a protruding rock. The air rescue helicopter arrived at the scene within 30 min, and the emergency physician and paramedic left the hovering helicopter that was unable to land due to inappropriate landing space. The child received an i.v. line, and immobilization of the cervical spine was performed. The girl was placed on a vacuum spine board to transport her to the place where the helicopter had landed, applying a scoop-and-run strategy. Table 1 shows the findings of the primary survey at the accident scene and their initial management.

Table 1: ABCDE parameters and findings at the scene of accident.

ABCDE parameter	Findings at the scene	Management
A	-	cervical spine immobilization device
B	respiration rate: 25/min, peripheral oxygen saturation not measurable, livid skin color, stable thorax	oxygen delivered by face mask at a flow rate of 10 L/min

C	heart rate: 140/min, capillary refill time: 3 s, skin color: pale-bluish cold peripheral skin temperature, peripheral blood pressure not measurable distended abdomen stable pelvis at first evaluation no obvious signs of external bleedings	i.v. line, application of 500 mL Ringer's lactate solution, tranexamic acid 500 mg applied i.v. immobilization of the spine using a spine board
D	GCS 6 (A1/V1/M4), no spontaneous leg movements, pupillae I + / I +	
E	found lying at a rock prominence	arrival time at the scene 30 min after the injury, scoop-and-run strategy

The child arrived at the A&E resuscitation room 1h after the injury. The respiration rate and pulse rate had increased to 40/min and 140/min, respectively. Blood pressure was now measurable (85/45 mmHg), and capillary refill time was 3 s. Pulse oximetry confirmed absent peripheral oxygen saturation. Endotracheal intubation and FAST were performed, and laboratory tests were ordered (Table 2). FAST examination revealed free intraperitoneal fluid around the liver and spleen and retroperitoneal anechoic fluid around the right kidney. The right-sided tension pneumothorax present was drained after emergency needle decompression by surgical insertion of a tube.

Table 2: Initial laboratory findings obtained after arrival at the emergency room.

Hemoglobin	100 g/L
Platelet count	202,000/L
International Normalized Ratio (INR)	1.65
Base excess	-13.4 mmol/L
pH	6.96
Lactate	10.0 mmol/L
Core temperature	35.9°C

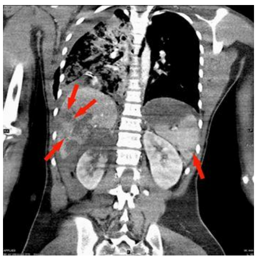

Figure 2: Contrast-enhanced CT scan obtained after admission: Liver laceration grade IV marked by arrows. Splenic rupture grade II marked by arrow. Hemopneumothorax visible on the right side.

Clinical findings and laboratory tests were indicative of a lethal triad, the life-threatening combination of acidosis, coagulopathy, and hypothermia (Table 2) [12]. Four units of O-negative packed red blood cells were ordered, and further i.v. administration of crystalloid fluids was limited to 500 mL. Subsequently, red blood cells, platelets, and pooled fresh frozen plasma (Octaplas®) were administered by two i.v. lines, and crystalloid fluid was stopped in accordance with the DCR strategy [1]. Overall, 500 mL of crystalloid fluid (11.2 mL/kg body weight) was administered during the flight, and 500 mL of crystalloid fluid (11.2 mL/kg body weight) was given in the resuscitation room.

Multiple trauma CT scanning revealed a centrally situated liver laceration grade IV, rupture of the spleen grade II, rupture of the right kidney grade III, and bilateral lung contusion together with right-sided hemopneumothorax (Figures 2-4).

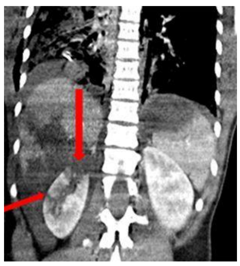

Figure 3: Contrast-enhanced CT scan obtained after admission showing laceration of the right kidney (marked by arrows). Note the centrally located liver rupture and hemopneumothorax.

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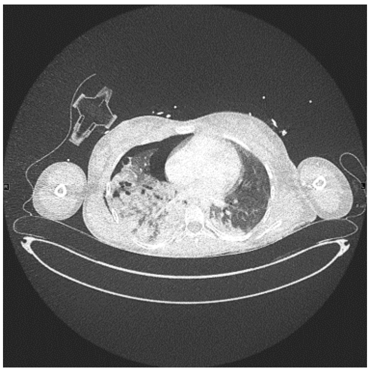

Figure 4: Contrast-enhanced CT scan of the thorax obtained after admission showing bilateral lung contusion and right sided hemopneumothorax.

In addition, we noted two stable pincer fractures of the thoracic spine, two transverse process fractures of the lumbar spine, and a fracture dislocation of the sacrococcygeal junction (Figure 5). The pelvic CT showed a central fracture dislocation of the left hip joint with intrusion of the head of the femur into the pelvis, and a pelvic retroperitoneal hematoma surrounding the fragments of the acetabulum (Figure 6).

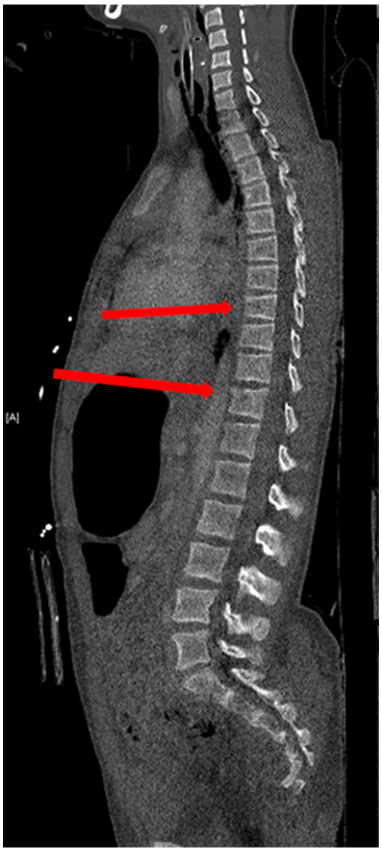

Figure 5: Contrast-enhanced CT scan obtained after admission showing 2 stable pincer fractures of the thoracic spine (marked by arrows) and dislocation of the coccyx.

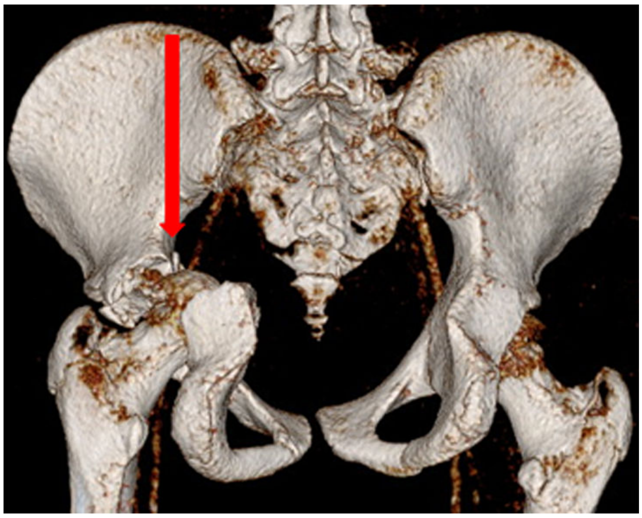

Figure 6: Three-dimensional CT-scan reconstruction of acetabulum fracture (arrow) with central dislocation of the femoral head.

Furthermore, a comminuted Salter-Harris type II injury of the proximal humerus (Figure 7) and small subdural hematoma in the frontal region without significant cerebral edema were found (Figure 8). Calculation of the Injury Severity Score (ISS) revealed a score of 48, indicative of life-threatening multiple trauma.

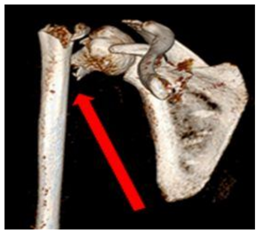

Figure 7: Displaced Salter-Harris Type II epiphysiolyis of the proximal humerus.

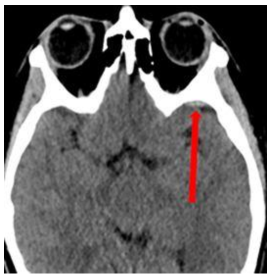

Figure 8: Cranial CT scan revealing small subdural hematoma (arrow).

Management of Injuries According to DCR Guidelines

We decided to resuscitate our patient with transfusions of packed red blood cells, fresh frozen plasma, and platelets and allowed for persisting hypotension because the brain swelling present was not considered dangerous and the most severe bleedings were located in the thoracoabdominal region. We decided not to open the abdominal cavity and closely monitored hemoglobin, blood pressure, pH, and lactate. In addition, we obtained ROTEM® blood coagulation variables at regular intervals (Figure 9).

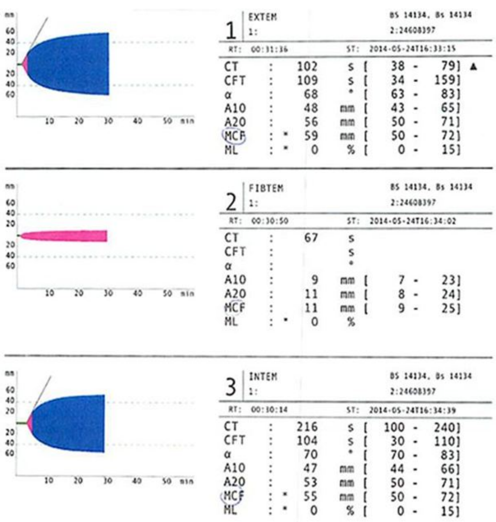

Figure 9: ROTEM® analysis obtained after admission showing prolonged clotting time (CT).

In accordance with the recommendation by Pandya et al. we applied a skin plaster traction (Buck's traction) to the leg for mild traction (traction force: 6% of body weight) at the dislocated hip joint for 24 h before reduction of the hip dislocation [2]. In the initial phase, we noted a trend towards stabilization of blood pressure, blood coagulation parameters, and acidosis and transferred the girl to the PICU for further treatment and rewarming. However, the operating theatre and an anesthetic-surgical team were on stand-by for 2 days in case any emergency laparotomy or thoracotomy would have been required.

On the first day after the injury, the child showed stable vital signs, and we decided to undertake closed reduction of the acetabulum fracture dislocation and percutaneous Kirschner wire stabilization of the displaced Salter Harris II fracture of the proximal humerus to facilitate the handling of the patient at the PICU (Figures 10 and 11).

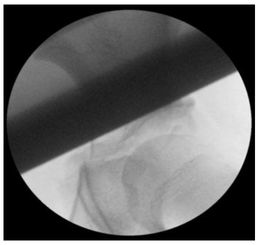

Figure 10: Reduction of dislocated left hip by longitudinal traction one day after admission achieving closed reduction of the acetabular fracture.

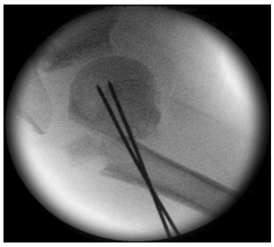

Figure 11: Stabilization of displaced Salter Harris Type II fracture of the proximal humerus by two percutaneously inserted K-wires. During this intervention, we undertook no attempt to perform a closed reduction of the fracture.

We refrained from time-consuming attempts to reduce the fracture of the proximal humerus in order to keep the intervention as brief as possible and minimally invasive. Thus, we planned to conduct open reduction and stabilization of both fractures as soon as the hemodynamic and ventilatory situation of the child had improved. We inserted a central venous line, and the skin plaster traction was applied again to the leg after successful reduction of the central acetabulum fracture dislocation.

Metabolic acidosis subsided within 3 days (Figure 12), and lactic acidosis normalized within one day (Figure 13). INR and platelet count returned to normal values within 6 days (Figure 14). We obtained blood coagulation tests and ROTEM® coagulation tests at regular intervals, confirming the continuous improvement of coagulation function.

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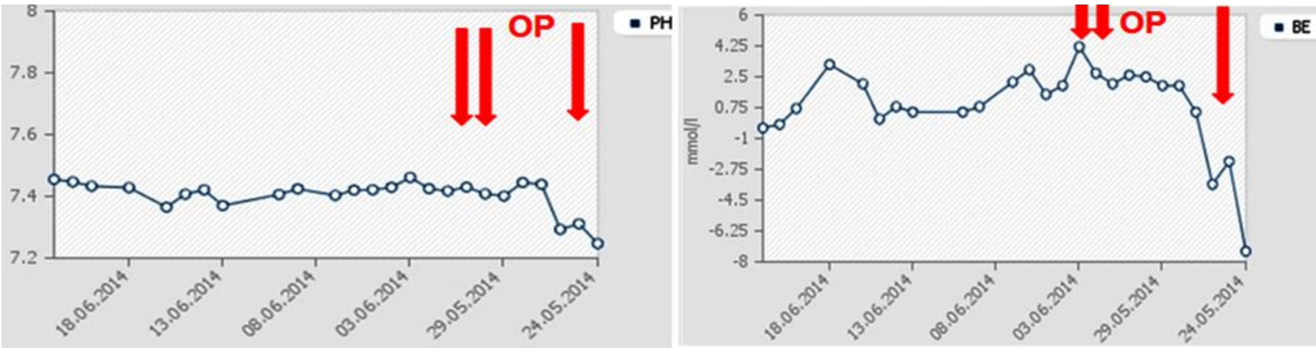

Figure 12: The slow recovery from shock ("permissive hypotension") resulted in a normalization of pH and base excess over the first days after the injury. The operative interventions (arrows) were postponed to allow for adequate recovery from shock. Time course from right to left.

Figure 13: Serum lactate values returned to normal one day after the injury. The timing of the operations is indicated by arrows. Time course from right to left.

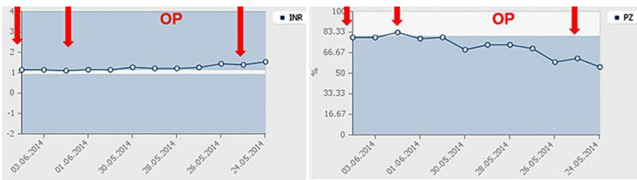

Figure 14: International Normalized Ratio (INR) and platelet count (PZ) returned to normal values within one week after the injury.

Creatine kinase values peaked 2 days after the injury (CK max: 11,000 IU/L). We instituted a forced diuresis infusion program on day 2, and creatine kinase levels returned to normal values within 5 days after the injury.

The elevated creatinine kinase values indicative of rhabdomyolysis returned to normal values within one week, and myoglobin crush injury to the kidneys was avoided. We monitored the urine output and creatine levels at regular intervals, bearing in mind that there was not only rhabdomyolysis but also rupture grade III of the right kidney (Figure 15) [9]. There was evidence of myocardial contusion, and serum markers of myocardial injury normalized within 4 days after the injury (Figure 15).

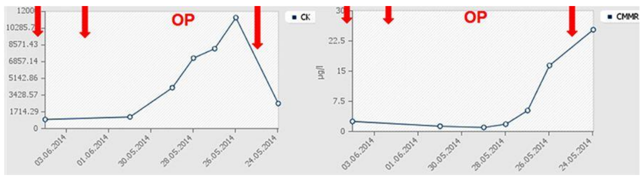

Figure 15: Massive elevation of creatine kinase levels during the first week after trauma. Myocardial-specific creatine kinase levels indicative of myocardial contusion returned to normal values within 4 days after the injury. Arrows indicate timing of the operative interventions.

Table 3 shows the volumes of blood products administered. The total volumes of blood and blood components given (3250 mL) represented more than a complete blood exchange (estimation of total blood volume: 3010 mL; blood volume: 70 mL/kg body weight, body weight: 43 kg).

Table 3: Blood products given during treatment.

	Packed red blood cells (mL)	Fresh frozen plasma (Octaplas®; mL)	Platelet concentrate (mL)
Transportation	0	0	0
A &E room	750	400	0
Pediatric intensive care unit (PICU)	1500	400	200
Total blood products (mL)	2250	800	200
mL/kg body weight	52.3	18.6	4.6

Nine days after the injury, we performed open reduction and plate fixation of the fracture of the acetabulum and an open reduction and intramedullary nail fixation of the fracture of the proximal humerus (Figure 16). We conducted a colposcopy because of a transvaginal bile-stained discharge. The bile-stained discharge originated from the portion of the uterus, and no injury of the vagina was present. Due to the long orthopedic operation time, the intervention was terminated after colposcopy, and we transferred the child again to the PICU. Four days later, a gastroenterologist performed endoscopic retrograde cholangiography (ERCG), which showed a disruption of the right hepatic duct (Figure 17).

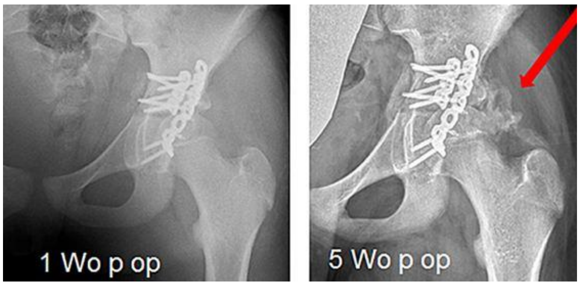

Figure 16: Plain X-ray of left hip obtained 1 week after the operation (left image) demonstrating reconstruction of the acetabulum with open reduction and internal fixation (ORIF) of the fracture. Right image: Massive heterotopic ossifications (arrow) surrounding the hip joint (5 weeks after ORIF).

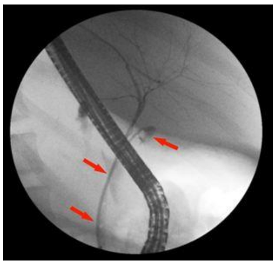

Figure 17: Endoscopic retrograde cholangiography (ERCG) demonstrating extravasation of contrast fluid indicative of hepatic duct rupture (arrow). Subsequently, a stent was placed by endoscopy into the choledochal duct to facilitate bile drainage from the choledochal duct into the duodenum (arrows)

A transpapillary stent was inserted into the common bile duct to facilitate the bile flow into the duodenum. We inspected the abdominal cavity, and bilious ascites was removed by suction. The bile duct stent was removed by endoscopy 10 weeks after the insertion, and the further course of the bile duct lesion was uneventful. Ultrasonic examination at follow-up 6 months after the injury did not reveal any dilatation of the bile ducts.

Figure 18: Cranial MRI scan obtained 10 days after the injury showing shearing injuries (arrow) and dissection injury of the internal carotid artery (arrow).

Two weeks after the injury, we were able to extubate the child. However, after withdrawal of the anesthetic medications, the girl showed a prolonged obtunded state. Magnetic resonance imaging (MRI) of the brain showed several small shearing injuries and an irregularity of the right internal carotid artery (Figure 18). MRI-angiography revealed a circumscribed dissection of the intima of the right internal carotid artery, together with posttraumatic stenosis of the internal carotid artery (Figure 19). Low-dose aspirin (100 mg/day administered orally once a day) was prescribed 2 weeks after the injury and was stopped after 6 months.

Figure 19: Cranial MRI-angiography showing narrowed segment of the internal carotid artery (arrow).

Psychiatric examination of our patient revealed a symptomatic transitory psychotic syndrome and reactive depression. Psychotherapy was instituted and antidepressant medication was prescribed. We started intensive physiotherapy, logopedic treatment, and occupational therapy, and the girl was instructed to walk without weight bearing of the left lower extremity for 2 months. She went home using crutches 6.5 weeks after the injury, and we organized an intensive out-patient rehabilitation program for her. She went back to school 10 weeks after the injury and did well in school, without losing a school year.

For a period of 6 months, the patient complained about neuropathic pain of the left sciatic nerve. We treated these neuropathic pain symptoms with pregabalin (LYRICA®), and the pain regressed within 6 months.

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Figure 20: MRI scan of the left hip obtained 8 weeks after the injury demonstrating partial avascular necrosis and bone bruise of the femoral head (arrow).

Eight weeks after the injury, we obtained an MRI of the hips which showed only mild partial avascular necrosis of the central portion of the femoral head (Figure 20). Subsequently, we allowed the girl to increase weight bearing by 5 kg per week until full weight bearing was achieved.

Radiological follow-up of the acetabulum fracture showed correct placement of implants and no secondary displacement of fragments, but moderate heterotopic ossification posterosuperior to the left hip joint was present (Figure 21).

Figure 21: Plain X-ray image of the right humerus obtained 8 weeks after the injury demonstrating consolidation of the fracture after open reduction and elastic stable internal fixation.

We decided to remove the intramedullary nails of the right humerus after 10 weeks, and we left the plates applied to stabilize the fracture of the pelvis and decided against removal of the implants in the region of the left acetabulum.

Figure 22: Our patient successfully finishing a city running event 18 months after the injury.

After one year, plain hip X-rays showed spontaneous partial regression of the periacetabular heterotopic ossification. Eighteen months after the injury, the girl took part in a city running challenge and finished the event without experiencing any problems (Figure 22).

Discussion

Our DCR strategy resulted in an excellent mid-term outcome of this patient. The child with an ISS of 48 and symptoms of the lethal triad (acidosis, coagulopathy, and hypothermia) at admission could be classified as an unexpected survivor. Damage control strategies have been developed in the battlefield at the end of the 20th century to improve the outcome of victims with severe trauma by fighting hemodynamic shock, compensating blood loss, limiting the administration of crystalloid solutions, and keeping the initial emergency surgical interventions short and minimally invasive [1].

The most important factors leading to trauma-induced coagulopathy (TIC) include acidosis, hemodilution, consumption of coagulation factors, and hypothermia [3]. Consumption of coagulation factors is triggered by activation of the coagulation system and activation of the anticoagulant protein C pathway [3]. In agreement with the recommendation of Christiaans et al., we applied point-of-care coagulation analysis including rotational thromboelastography (ROTEM®), applied at short intervals after admission for early detection of blood coagulation alterations [3,13]. A major benefit of thromboelastography (TEG®) and ROTEM® is their ability to evaluate coagulation function in whole blood in a very short time [3]. Measurement of coagulation function of whole blood using TEG® in children with severe trauma was recently reported [14]. We used the analysis of interim ROTEM® values A10 in our patient, in accordance with the recommendation of Wooley et al. that are proposed to monitor and restore coagulation function in adults [15].

In the presence of acidosis, hypothermia, and hypotension in patients with an ISS >25, as was present in our patient, the probability of developing trauma-induced coagulopathy (TIC) is considered 98% [16]. Physiologic and iatrogenic hemodilution in trauma patients can act as a driver of TIC [3]. TIC is observed in 40% of trauma patients who received more than 2000 mL of i.v. fluid during the prehospital phase [17]. Therefore, we limited the volume of injected crystalloid fluid (Ringer's solution) during and after the patient transfer to 11 mL/kg bodyweight [17]. The ionic composition of Ringer's solution equals that of plasma, whereas normal saline solution is associated with hyperchloremic metabolic acidosis [18].

In most patients receiving low volumes of crystalloid fluid during DCR treatment, systolic blood pressure increases steadily [6]. This phenomenon is attributed to changes in vascular resistance [19]. The use of more blood products but less crystalloid fluid is the mainstay of DCR [6]. It has been shown that administration of a moderate volume of crystalloid solution (700 mL) in the prehospital setting was associated with improved survival [20].

The early development of acute coagulopathy of trauma (ACOT) is associated with increased transfusion requirement and mortality [21]. Coagulation function is slowed down by 5% with each degree loss of body temperature (°Celsius) [22]. In addition, acidosis of pH 7.2 reduces the activities of coagulation factors by 50% [23]. In our patient, the pH measured at admission was 6.96; therefore the activity of coagulation factors was considered severely impaired. In accordance with a report of a child with pelvic trauma who received fibrinogen after ROTEM® testing, we administered 1.0 g of fibrinogen after obtaining the ROTEM® results and subsequently applied ROTEM-controlled coagulation factor replacement therapy [24]. The CRASH-2 study examining the effect of early administration of tranexamic acid (TXA), a potent antifibrinolytic agent, after severe trauma showed a significant decrease in death due to bleeding when TXA was administered early after trauma in adults [25]. The pediatric trauma and tranexamic acid study (PED-TRAX) investigated the early (< 3 h after injury) administration of TXA in children [26]. TXA use in this setting was associated with a survival advantage and better neurologic outcome at discharge [26]. Therefore, 500 mg TXA was administered during transportation by the helicopter emergency physician in our patient.

Large-volume transfusion (LVT) is defined as transfusion of 50% of blood volume equivalent or greater, whereas massive transfusion (MT) is defined as transfusion of 100% of blood volume equivalent within 24 h or greater, using a standard weight blood volume calculation [26]. In our young patient, LVT was applied.

Treatment of pediatric polytrauma at a pediatric trauma center may decrease the risk of mortality in children suffering from severe multiple injuries [27]. Patients suffering from splenic injuries managed at pediatric centers are less likely to undergo splenectomy than those managed at nonpediatric centers [28]. Today, more than 90% of splenic injuries in children are managed without surgery, and management of these injuries showed a lower complication rate when compared to surgical management [28,29]. Guidelines for the nonsurgical management of splenic, hepatic, and renal trauma in children are widely accepted [30,31]. According to Bansal et al. criteria for laparotomy to treat splenic injuries comprise hemodynamic instability with evidence of massive bleeding on presentation or children who required transfusion of more than half of their blood volume within 24 h after the injury [30].

In adults, immediate operative management of severe blunt liver injuries (grades IV and V) is warranted in one-third of patients [32]. Two of three adult patients can be managed by a nonoperative approach, and failure of nonoperative management (fNOM) occurs in 23% of these patients [32]. However, the very low complication rates in successful and failed nonoperative treatment groups (5.4% vs. 8.7%) were not significantly different [32]. Non-surgical management has also been successfully applied in more than 80% of adult patients suffering from hepatic trauma, and a marked decline in death rates over the 25-year interval was noted [33]. Deaths related to liver injury were caused by hemorrhage in 85% of patients [33]. Non-surgical treatment has allowed major venous injuries to be managed without surgery [33]. Packing led to survival in >60% of patients [33]. The authors concluded that because venous injuries occur in the low-pressure system, many injuries heal without the need for surgery [33].

In our patient, rupture of the right hepatic duct caused bilious ascites. ERC intervention and stent insertion into the choledochal and hepatic duct and laparoscopic drainage of the bilious ascites 2 weeks after the injury must be considered an fNOM [32]. Van der Wilden et al. reported that adults who had suffered severe blunt liver injuries (grades IV and V) were more likely to experience fNOM if systolic blood pressure was low (<100 mmHg) and intra-abdominal injuries were present. Both these conditions were also present in our patient. ERC was conducted in 16/393 (4%) of their patients, and drainage was necessary in 14/393 patients (3.6%). Laparoscopy was performed in 2/393 patients (0.5%) [32].

In our patient, we performed neither angiography nor embolization. In a multicenter study in adults with severe blunt liver injuries, van der Wilden et al. reported hepatic angiography in 35.9% and embolization in 24.8% of their patients [32]. Angiography, embolization, and endoscopic interventions play an important role in the management of severe liver injuries without surgical intervention [33,34].

Fraser et al. recommend obtaining initial CT-scans for any child with hematuria especially in the presence of pelvic trauma [35]. Ultrasound may be useful to screen hemodynamically unstable patients who are unable to undergo CT. Wessel et al. recommended that only grades IV and V renal injuries in children should be operated [36]. This would result in a conservative management rate of renal injuries in children of >90% [36]. Nance et al. described a management strategy for blunt renal injuries in children which resulted in a 95% non-operative rate with a 99% renal salvage rate [37]. Schreiber et al. compared the renal function outcome of reduced-volume resuscitation in adult trauma patients to the renal function outcome of standard-volume resuscitation and noted no significant difference between the groups [6]. However, it must be noted that one patient in this series died from tension pneumothorax [6].

Among 605 children suffering from intra-abdominal solid organ injuries, 17 (4.1%) children required therapeutic laparotomy; while 6 (1.4%) children were treated with embolization and 46 (11%) received blood transfusions [38]. In this study, 10 of 605 children underwent laparoscopy, and none of them underwent therapeutic laparoscopic interventions.

Among children with intra-abdominal injuries, 76% had free intraperitoneal fluid [38]. This finding has implications for the reliability of FAST examinations [39].

Acetabular fractures are very rare in children and occur predominantly in older children [40]. Retroperitoneal bleeding is usually less pronounced in children suffering from acetabular fractures than in children suffering from pelvic ring disruptions. Early stabilization with pelvic binders or external fixation may help to decrease the blood loss in pelvic ring disruptions by reduction of the pelvic space, but this may

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increase the dislocation of fractures of the acetabulum. Disruptions of the triradiate cartilage are very rare and difficult to diagnose in children [41]. Injuries to the growing acetabulum can result in premature closure of the triradiate cartilage and acetabular dysplasia [41].

Early osteosynthesis of long bone fractures within the first 72 h after injury has been shown to shorten hospital stay, intensive care unit stay, and length of time of ventilator support [42]. Therefore, we reduced the fracture dislocation of the acetabulum and undertook an emergency percutaneous K-wire stabilization of the displaced fracture of the humerus one day after the injury to ensure better handling of the child at the PICU. The definitive orthopedic treatment was postponed to day 9 after the injury. Damage control orthopedics (DCO) has the advantage to minimize blood loss, limit the operation time, and reduce mortality in adult patients suffering from severe multiple trauma [43]. However, no prospective pediatric studies examining the potential benefits of DCO on hypothermia, hypoxemia, and blood loss are currently available [43,44].

Conclusion

DCR contributed to the successful outcome in this severely injured 12-year old girl suffering from hemorrhagic shock and multiple injuries. To confirm the clinical efficiency of DCR in children, prospective, randomized trials are required.

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