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Management of a Vertical Impalement Injury

Selzer Tabea[1]; Grzybowski Leszek[1]; Rocco Barile La Raia[2]; Horst Hahn[3]; Lemke Arne-Joern[4]; Hueseyin Bektas[1]*

[1]Klinik für Allgemein,- Viszeral- und Onkologische Chirurgie, Klinikum Bremen-Mitte.

[2]Klinik für Thoraxchirurgie, Klinikum Bremen-Mitte.

[3]Fraunhofer Insitute for Digital Medicine (MEVIS) Bremen.

[4]Zentrum für Radiologie, Klinikum Bremen-Mitte.

***Corresponding Author(s): Hueseyin Bektas**

Klinik für Allgemein,- Viszeral- und Onkologische Chirurgie, Klinikum Bremen-Mitte.

Tel: 004942149773602 & 0049421497 1973699;

Email: hueseyin.bektas@gesundheitnord.de & profbektas@gmail.com

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Introduction

An impalement injury is typically a severe and challenging trauma that necessitates close interdisciplinary collaboration among specialized medical disciplines. The rescue chain involves the mobilization of emergency services, initial treatment by the paramedic, transportation, care, and diagnostics in the emergency department of the appropriate hospital, surgical intervention, and the required follow-up care. Only through a seamless progression of the rescue chain can such an injury be effectively managed, ultimately leading to the successful treatment and rescue of the patient. Fortunately, in the majority of impalement injuries, only one compartment of the body is affected. However, in a few cases, two or more body cavities or compartments may be involved, significantly complicating the treatment. It is crucial not to overlook that an impalement injury constitutes not only a penetrating and perforating injury affecting multiple organs but also poses a substantial risk of infection. In cases of isolated thoracic or abdominal injuries, the mortality rate is estimated to be between 25-40% [1].

Case presentation

We would like to report the case of a 55-year-old patient (75kg, 185cm, BMI 22) with an impalement injury affecting two body cavities. In this case, the focus should be directed towards the impeccable supply chain.

The patient fell from a 4-meter-high ladder while working on trees, landing on a metal rod of the fence in his garden. The 3.5 cm diameter metal rod caused a longitudinal injury along the body axis. The metal rod penetrated perineally, passed through the rectum and prostate, traversed the pelvic cavity, entered the abdominal cavity passing by the iliac vessels and bladder, perforated the cecum, passed by the ascending colon and the right colonic flexure, ascended over the right lobe of the liver, penetrated the diaphragm, traveled above the right lung and heart without causing injury, passed through the thoracic wall, and exited the thorax in the intercostal space 3/4 towards the exterior. Merely a partial fracture of the fourth rip could be detected (Figure 1-4).

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After the fall the patient was impaled lengthwise by the metal rod, hanging free in the air. He was conscious and cooperative. After short time he realized he was slowly sliding down the rod and asked his son to put something under his feet to stabilize him. His 21-year old son put a chair under his father's feet to prevent him from further sliding. Afterwards he made an emergency call. While waiting for the rescue team the patient had felt no pain, he only noticed increasing warmth.

Rescue chain

Immediately after arriving, the paramedic doctor established a venous access and administered fluids and pain medication. For the further rescue, an emergency medical helicopter has been requested. Following this first treatment the patient was stabilized by the fire brigade and the rod was cut of the fence so that the patient could be placed on a stretcher with the remaining impaled rod. Subsequently the patient was intubated and transported by helicopter to our hospital, a hospital of comprehensive care (Figure 1).

Diagnostic

Arriving in our emergency department the patient was immediately admitted to our trauma room where an interdisciplinary team consisting of traumatologists, abdominal surgeons, thoracic surgeons, anesthesiologists and nurses of the emergency room was awaiting the patient. After taking blood samples, which showed mostly normal results, a tetanus vaccination was applied as well as prophylactic antibiotics. Simultaneously an ultrasound examination was performed, without any signs of acute bleeding. A polytrauma CT scan was initiated.

The polytrauma CT scan is a full-body contrast computed tomography including cranial CT, CT of the entire Spine, thoracic-, abdominal- and pelvic CT. The following results where shown: Caudocranial impalement injury with an iron rod (37mm diameter) from perineal to pectoral right, without injury of any major vessels, as far as assessable despite metal artifacts. An impalement of the liver ventral the gallbladder in segments Iva/b as well as the middle lobe of the lung cannot be excluded. Small amounts of free air in the upper abdomen as an indicator for a possible bowel perforation. Pleural effusion on the right (Figure 7a-d). No fractures.

Immediately after the CT scan the surgery was planned, performed by surgeons of the thoracic surgery and abdominal surgery simultaneously.

Surgical care

First of all the patient was re-intubated with a double lumen endotracheal tube to secure the one sided ventilation of the left lung during surgery. Afterwards the patient was placed on his back on the operating table, the right chest lifted in an angle of 45 degrees of the table. The surgery started with a thoracotomy in the 5th ICR while one sided ventilation of the left lung. In the following inspection no injury of the lung, heart or major vessel could be detected. At the same time a median longitudinal laparotomy was performed, followed by a thorough exploration of the intraabdominal cavity with mainly normal result. Merely a perforation of the cecum was presented. Neither vital organs nor structures were injured in the abdominal nor thoracic cavity. The rod entered the body perineal, went through the pelvic cavity, missed the iliac vessels, bladder and ureter, perforated only the cecum, went further up upon the liver, heading towards the thoracic cavity, perforating the diaphragm, traversed the thoracic cavity, without injuring the lung or the heart and exited the thorax in the intercostal space 3/4 towards the exterior.

After the careful exploration the rod could be removed from perineal under visual and manual control.

After the removal of the rod first the diaphragm was attended. The perforation site was debrided and closed with several stitches. Afterwards the thoracic cavity was rinse with several liters of saline solution and two thoracic drainages were placed. Next the thorax was closed by stitches and the abdominal part of the surgery followed. First the perforation of the cecum was treated. An ileocecal resection was performed and by side-by-side ileoascendostomy reconstructed. After a thorough lavage of the abdominal cave, the inspection of the rectal area followed. First, a digital rectal examination was done and showed no injuries of the rectum. Afterwards a rectoscopy up to 17cm followed, in which also no injury could be detected. The point of entry was found next to the anal canal at 9 to 11 o´clock in lithotomy position. The rectum itself was unharmed and the perfusion was normal. The entry wound was flushed out serval times and an Easy flow drainage was established.

Now the abdominal cave was attended again and checked for bleeding and other injuries. Since none were found, drainages were placed next to the resection site and in the Douglas Pouch. Next the abdominal wall was closed.

During the entire surgery, the patient showed stable vital signs. Afterwards the patient was transferred to our intensive care unit. Shortly after being admitted to the ICU, the patient could be extubated and after two more days he was transferred to the normal ward (Figure 5).

The further progression there was mostly unremarkable. He was able to recover swiftly and regain mobility, under antibiotic therapy. The nutritional rehabilitation could be started promptly. The endosonographical report presented a blunt trauma to the anal sphincter with a partial tear at 6-9 o'clock lithotomy position. Since no symptoms of incontinence were present and the finding was diffuse, the injury was left to heal conservatively. After approximately three weeks postoperatively, a rethoracotomy was performed, due to a thoracic empyema. The empyema was then cleared out.

The patient and his family received postoperative psychological support to process the trauma.

Finally he was able to be released four weeks after the trauma, without physical limitations and in good health.

The succesfull outcome was a result of expert teamwork between different subspecialities and timly intervention followed by transport, diagnostics, extraction of the Steel rod and subsequent repair of the affected organs that involved [2-4].

Figure 1: Patient with the rod in the body after intubation by the emergency physician.

Figure 2: Overview image during polytrauma CT in the emergency room.

Figure 3: Reconstruction of the CT images by the Center for Radiology at Bremen-Mitte Hospital.

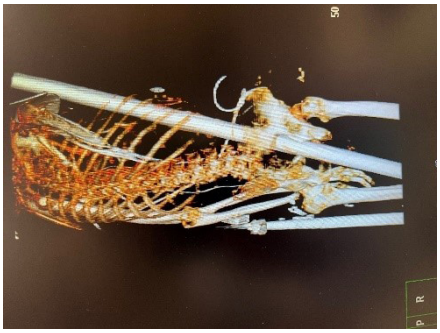

Figure 4: Reconstruction of the CT images by the Center for Radiology at Bremen-Mitte Hospital.

Discussion

Impalement injuries involving multiple body cavities and compartments are fortunately extremely rare and, in most cases, unfortunately result in fatality. Injuries as in our case, affecting several body compartments, are rare. The most striking aspect may be that no vital organs were pierced. The longitudinal impalement from perineal to thoracic intercostal space could have severely damaged liver, iliac vessels, lungs, and heart amongst others. The path taken by the metal rod may have a significantly low chance of occuring, which may mean the patient was fortunate in the sense that the severe injury might have been even more serious.

Figure 5: Patient one week postoperative. He is mobile and has started eating. He wanted to keep the rod and took it with him.

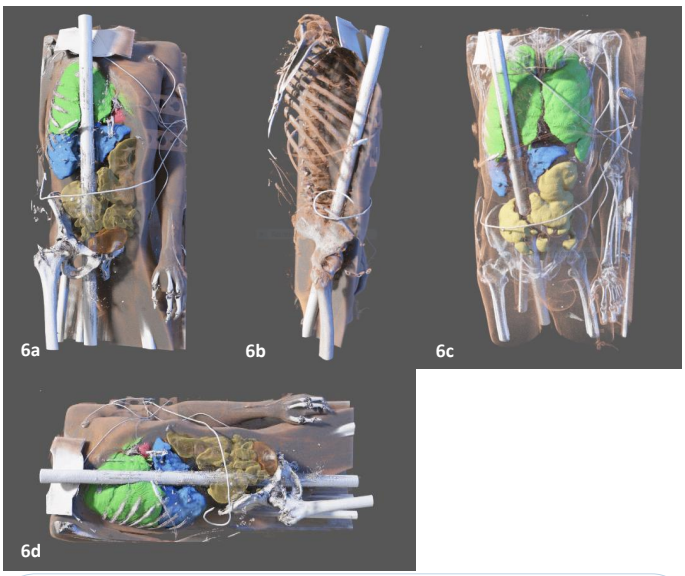

Figure 6a-d: Reconstruction with the help of artificial intelligence by Fraunhofer Institute for Digital Medicine MEVIS (Florian Link), in which the extraction of the organs from the foreign body was entirely possible.

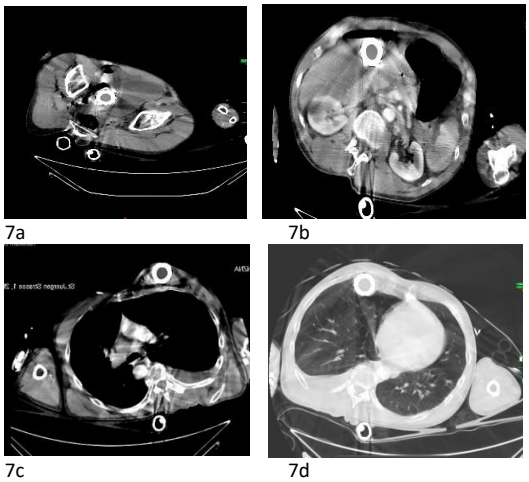

Figure 7a-d: CT scans as part of polytrauma CT; transverse slice, pelvis, abdomen, thorax

Another consideration is the fact that the 3.5 cm diameter metal rod was rusted. Therefore, it was naturally not sterile and possibly infiltrated with various germs. Furthermore, the rod

perforated the coecum and transported intestinal bacteria into the abdominal cavity and thoracic space. During the operation we were indeed able to remove food residues from the aforementioned two cavities. The patient was able to recover swiftly and be released without any lasting damages, not long after the primary injury.

Here in Germany we ware able to managed this inhjury according the suggetion of [5] (Table 1). They have emphasized 3 principles of managing impalement injuries however most applicable in developed nations.

In the ICU, a polytrauma CT scan without extremities was performed, in order to present the injury. These images were examined still in the ICU and were partially reconstructed, even before the patient was taken to the operation room.

Table 1: Principles of management of impalement injury [5].

1	The pre-hospital providers should leave the impaled object in situ to provide a possible tamponade effect and permit the focus on rapid transport as the goal.
2	The patient should be rapidly stabilized and transported, preferably to a trauma center and.
3	The patient should be rapidly assessed and resuscitated in the emergency department, avoiding any unnecessary tests that delay care, and then transported to the operating room for definitive care.

Later, the tomographic images were both reconstructed in our radiology department (Figure 2-4, 7 a-d) and in the Fraunhofer Institut für Digitale Medizin MEVIS in Bremen, with the help of an nnUnet based AI automated image segmentation method (Figures 6 a-d). Hereby, it was possible to differentiate between organs, bone structures, and the foreign object. A conventional CT scan leads to superimposition artifacts when metal objects have perforated a patient. To the best of our knowledge, it may be the first time that AI differentiated between organs of the abdominal, pelvic, and thoracic cavity and a foreign metal object of several centimeters diameter. In this case, every single organ and the foreign object were able to be visualized precisely. Therefore, the perspective of using AI primarily in emergency diagnostics naturally presents itself, in order to plan operations meticulously.

Regarding such an injury, the attention should be placed on the impeccable rescue chain. This may have been optimal in every aspect of this case. Beginning with the 21-year-old son of the patient, who placed a chair under the feet of his father, to stop him from falling further onto the rod and called the fire department and emergency doctor. In Germany, in such cases, the fire department typically responds with the necessary technical equipment and trained professional personnel. They free the injured party while adhering to all necessary precautions for the patient, rescue personnel, and other involved parties. The emergency doctor acted in an extremely professional manner, was able to provide primary care for the patient, and rightfully requested a helicopter, which transported the patient to the correct hospital, where all necessary specialized departments were available [2]. The patient was freed from the fence by the fire department, however the rod was correctly not removed. Afterwards, he was intubated and ventilated by the emergency physician and transported to us by helicopter. Most probably, the patient might not have survived the injury, if not for this gapless, optimal, and highly professional rescue chain. This remarkable case shows, that even if an injury seems to be too severe at first, one should never give up and saving a patient can indeed be possible, if the chain of treatment works flawlessly.

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Ethical Approval: Patient gave us informed consent and ethical approval was not required.

Consent: Written informed consent is obtained from the patient for publication of this case report and any accompanying images.

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