10.5005/jp-journals-10030-1158

REVIEW ARTICLE

Object impaled in the Thorax: Review Study

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ABSTRACT

Aim: The aim of this study is to describe the management of a patient who presents with a penetrating chest trauma due to impalement by an offending object, be it a knife, metal structure, or other type of object.

Background: Until today, many institutions have treated this type of injury with urgent thoracotomy, despite advances in thoracoscopy and radiologic studies. A review was performed principally to discuss the use of nonoperative treatment, thoracoscopy, and thoracotomy. Thirty-two patients described as case reports in 27 articles were reviewed to carry out this descriptive study. For each patient, the following variables were studied: Age, gender, trauma mechanism, hemodynamic stability upon admission, treatment type, injuries encountered and associated with the condition, complications, and the final disposition of death *vs* survival.

Review results: Twenty-one patients were treated with thoracotomy or sternotomy, seven patients with removal of the impaling object without surgery, and five patients with removal of the object using thoracoscopic assistance (one patient was treated with the assistance of thoracoscopy on the right side and with direct removal on the left side). A summary of the evidence reviewed is provided in a flowchart.

Conclusion: With technological advancements, especially in thoracoscopy and computed tomography, many of these injuries are responsive to less invasive treatment. Thoracotomy, considered the standard of care in many trauma centers, can be reserved for specific cases.

Clinical significance: Pursuant to some of the criteria listed in this study, as occurs in our institution, the thoracotomy rate can be reduced, thereby reducing mortality and benefiting patients.

Keywords: Penetrating, Thoracoscopy, Thoracotomy, Thorax, Trauma, Wounds.

How to cite this article: Botelho-Filho F, Drumond DAF, Starling SV, Peixoto LC, Zille DP, Constantino GDC. Object impaled in the Thorax: Review Study. Panam J Trauma Crit Care Emerg Surg 2016;5(3):148-154.

Source of support: Nil

Conflict of interest: None

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RESUMO

Objetivo: O objetivo desse estudo é descrever a abordagem de um paciente vítima de trauma torácico penetrante com objeto envravado, seja ele uma faca, estrutura metálica ou outro tipo de objeto.

Cenário: Até hoje, muitas instituições tem tratado esse tipo de trauma com toracotomia de urgência, apesar dos avanços na toracoscopia e nos estudos radiológicos. Sendo assim, foi realizada uma revisão principalmente para discutir a abordagem conservadora, o uso da toracoscopia e da toractomia. Trinta e dois pacientes descritos como relato de caso em 27 artigos foram revistos nesse estudo descritivo. Para cada paciente foram estudads as seguintes variáveis: idade, sexo, mecanismo de trauma, estabilidade hemodinâmica na admissão, tipo de tratamento, lesões encontradas, compicações e óbito.

Resultados da revisão: Vinte e um pacoentes foram tratados com toracotomia ou esternotomia, sete pacientes com remoção direta do objeto encravado, sem procedimento cirúrgico adicional e cinco pacientes foram tratados com a remoção do objeto, guiado por toracoscopia (um paciente foi tratado com toracoscopia do lado direito e com remoção direta do outro lado). Uma proposta de conduta, após a revisão dos casos, foi sumarizada em um fluxograma.

Conclusão: Com os avanços da tecnologia, especialmente na toracospia e na tomografia computadorizada (TC), muitas lesões podem ser abordadas com um tratamento menos invasivo. A toracotomia, considerada o padrão em vários centros de trauma, pode ser reservada para casos específicos.

Significância clínica: Seguir alguns critérios listados nesse estudo, com são seguidos em nossa instituição, pode reduzir a taxa de toracotomia, reduzindo a taxa de mortalidade e beneficiando os pacientes.

Palabras claves: Ferimentos penetrantes, Tórax, Trauma, Toracoscopia, Toracotomia.

INTRODUCTION

Penetrating wounds to the chest through impalement by an offending object are injuries that cause mild to severe trauma. They can be life-threatening and may require urgent thoracotomy.[1]

Upon hospital admission, these patients can be shocking to staff due to the dramatic nature of their injuries (Fig. 1). Consequently, service is often unnecessarily disturbed and disrupted, which should not occur in a hospital trauma setting.[2]

The removal of an impaling object, leading to exsanguination and death, was first described by Bill in 1862 after the removal of an arrow on a battlefield. This event led to the recognition of the blocking effect promoted by the impaled object, particularly in larger vessels.[3]

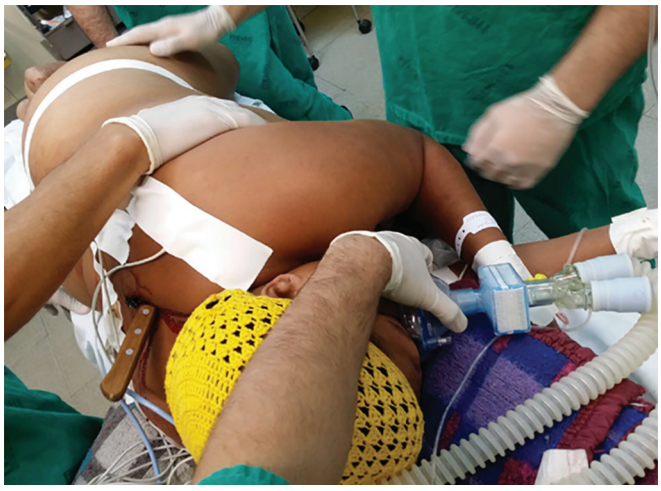

Fig. 1: A victim of stab injury

However, despite the importance of this finding, it also created fear in many surgeons, who usually do not look beyond exploratory thoracotomy, regardless of the type of injury and diagnostic resources available, such as angiography and computed tomography (CT). The fact that the literature is based on a small number of case reports[4,5] and the lack of experience with this type of trauma further consolidate this fear.

The general and trauma surgery service of our hospital, therefore, decided to review the literature and propose a way to manage this type of trauma injury to reassure the surgeon who addresses it.

It is important to establish that this is a study about a specific type of injury: A chest injury characterized by an offending object through the thoracic wall at the moment of the admission.

We performed our research by searching PubMed for the following sets of words: "Impalement thoracic injury," "impalement thorax injury," "chest impalement injury," "retained object thoracic injury," and "retained object thorax." We limited the research by language (English, Spanish, or Portuguese) and articles that reported human cases.

Sixty-seven articles were found. The following articles were excluded: Twelve articles about an offending object that was not found in the thorax but in a different anatomic area, 14 articles about an offending object that was not present at the moment of admission or that was intrathoracic, and 22 articles that were unavailable through our servers or articles that were actually letters or comments or insufficient with regard to data. These articles included a large number of older articles. We added 8 more articles based on the references of the articles that we first identified.

Ultimately, 27 articles and 32 patients were included in this review.[1,2,4,6-28] For each patient, the following variables were studied: Age, gender, trauma mechanism, hemodynamic stability on admission, treatment type (exclusive removal, removal under thoracoscopy, and removal under thoracotomy), injuries encountered and associated with the condition, complications, and the final disposition of death *vs* survival.

At the end of the review, the results were tabulated for descriptive analysis.

REVIEW RESULTS

The results are shown in Table 1.

The mean patient age was 33.12 years (17–78 years), and the majority of patients were male patients (84.37%). The most common trauma mechanism was falling (25%),[6-13] followed by physical assaults[1,14-17] and car accidents (21.8% each)[1,4,6,18-22] with impalement by car fragments. These three causes therefore, accounted for over 68% of trauma mechanisms.

The main injuries noted were hemothorax (43.75%), lung laceration (40.62%), pneumothorax (28.12%), rib fracture, and pulmonary contusion (25% each).[1,2,4,6-26] Other injuries (3–15%) included injuries to the following: Heart, esophagus, diaphragm, right bronchus, thoracic vertebrae, thoracic aorta, scapula, sternum fracture, and lung laceration with rib fracture.[4,6-28] It is noteworthy, however, that diaphragmatic injury was present in 15.62% of patients, indicating abdominal injury.[2,9,12,16,26] In that group, all of the patients had intraabdominal organ injury (4 liver injuries, 1 splenic injury, and 2 hollow viscous injuries). Some studies described only the most significant injuries, whereas other studies did not describe the injuries, which may explain the low incidence of pulmonary lesions. There was 1 case in which a transfixing cardiac injury was treated, while the patient remained in extracorporeal circulation.[12]

The most affected side was the right side, accounting for 43.75% of cases, and thoracoabdominal injuries were present in 18.75% of cases.

Mediastinal injuries or those traversing the midline were present in 28.12% of cases. A close relationship was observed with the performance of CT imaging in this subgroup of patients: Approximately 60% of these patients underwent tomographic imaging compared with the average rate of 35%. In two cases, despite tomography or aortography excluding any noteworthy injury, the patients underwent thoracotomies that corroborated the initial findings.[10,25] This result is relevant because it demonstrates that tomography and aortography could offer guidance to be more parsimonious with surgery.

Regarding treatment, 21 patients underwent thoracotomy, and only 5 were unstable upon admission.[1-4,7-13,15,19-27] Another therapeutic option carried out was removal of the impaled object under thoracoscopy (5 patients),[6,14-16,18,24] and all of these patients were stable upon admission.

Table 1: Relationship between studied patients and their characteristics

Patient/Reference	*Age*	*Gender*	*Trauma mechanism*	*Hemodynamic stability on admission*	*Test performed*	*Treatment*	*Injuries found*	*Associated injuries*	*Complications*	*Death*
1/(Davies et al 2009)	37	M	Fall	Yes	CT	Removed without direct view of surgical blockage	–	–	n/c	No
2/(Darbari et al 2005)	18	F	Assault	Yes	–	Removed without direct view of surgical blockage	Pulmonary contusion, unstable chest, rib fracture	–	Surgical wound infection, sepsis, graft/ flap loss, respiratory failure	Yes
3/(Darbari et al 2005)	35	M	Motorcycle accident	Yes	Chest X-ray	Thoracotomy	Rib fracture, pneumothorax, pulmonary laceration, esophageal injury	–	Surgical wound infection	No
4/(Thomson and Knight 2000)	43	M	Explosion	Yes	Chest X-ray	Thoracotomy	Pulmonary contusion, pulmonary laceration, esophageal injury, diaphragmatic injury	Hollow viscera abdominal injury, liver injury	n/c	No
5/(Hyde et al 1987)	27	F	Car accident	Yes	–	Thoracotomy	Rib fracture, pulmonary laceration	MMIIs fracture	n/c	No
6/(Hyde et al 1987)	36	M	Car accident	Yes	Chest X-ray	Thoracotomy	Rib fracture, fracture of the scapula	–	n/c	No
7/(Hyde et al 1987)	26	M	Car accident	Yes	–	Thoracotomy	No injury	–	n/c	No
8/(Fradet et al 1988)	33	M	Nonintentional penetrating injury	Yes	Chest X-ray/ CT	Thoracotomy + Laparotomy	Pulmonary contusion, hemothorax, thoracic aortic injury, thoracic vertebra Injury, diaphragmatic injury	Liver injury	n/c	No
9/(Burack et al 2005)	25	M	Assault	Yes	Chest X-ray	Thoracoscopy	Hemothorax, pulmonary laceration, pulmonary contusion	–	n/c	No
10/(Frangos et al 2006)	52	M	Assault	Yes	Chest X-ray/ CT FAST	Removed without direct view of surgical blockage	Hemothorax, pneumothorax	–	n/c	No
11/(Davis et al 2003)	38	M	Car accident	No	–	Thoracotomy + laparotomy	–	–	Respiratory failure, abdominal compartment syndrome	Yes
12/(Williams et al 2006)	23	M	Assault	Yes	Chest X-ray/ CT FAST	Thoracoscopy	Hemothorax, diaphragmatic injury	Liver injury	n/c	No
13/(Williams et al 2006)	23	M	Assault	Yes	Chest X-ray	Thoracoscopy	Pneumothorax, pulmonary laceration	–	Sustained pulmonary fistula	No
14/(Shikata et al 2001)	36	M	Fall	Yes	Chest X-ray	Sternotomy	Pulmonary contusion, pneumothorax, bronchus D injury	MMIIs fracture	Respiratory failure, perioperative bleeding	No

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Patient/Reference	Age	Gender	Trauma mechanism	Hemodynamic stability on admission	Test performed	Treatment	Injuries found	Associated injuries	Complications	Death
15/(Shimokawa et al 1994)	33	M	Nonintentional penetrating injury	Yes	Chest X-ray/ CT	Thoracotomy	Chest, cardiac, and esophageal vertebrae injury	–	n/c	No
16/(Mathur et al 2013)	20	M	Nonintentional penetrating injury	Yes	Chest X-ray/ CT	Removed without direct sight of surgical blockage	Pulmonary laceration, hemothorax, cardiac injury	–	n/c	No
17/(Cartwright et al 2001)	29	M	Car accident	Yes	–	Thoracotomy	Pulmonary contusion, rib fracture, clavicle fracture	–	Perioperative bleeding	No
18/(Bar et al 1998)	63	M	Assault	Yes	Chest X-ray	Thoracoscopy	Pneumothorax, hemothorax	–	n/c	No
19/(Chui et al 1998)	24	M	Nonintentional penetrating injury	Yes	Chest X-ray/ CT Aortography	Thoracotomy	Hemothorax, chest vertebra injury, mediastinal hematoma	–	n/c	No
20/(Okumori et al 1981)	31	M	Fall	Yes	Chest X-ray	Removed without direct view of surgical blockage	Hemothorax	Face trauma	Perioperative bleeding	No
21/(Kaur et al 2014)	35	M	Fall	Yes	–	Thoracotomy + laparotomy	Pulmonary laceration, diaphragmatic injury	Splenic and colon injuries	n/c	No
22/(Ruano et al 2014)	19	M	Motorcycle accident	No	–	Thoracotomy	Pulmonary laceration, rib fractures	–	Atelectasis, renal failure, rhabdoyolysis, pulmonary sepsis, acute respiratory distress, empyema	Yes
23/(Wimalachandra and Asmat 2014)	24	M	Work accident	Yes	CT	Sternotomy	Mediastinal hematoma, sternum fracture	–	n/c	No
24/(Lunevicius and O'Sullivan 2014)	17	M	Assault	No	CT/X-ray	Removed without direct view of surgical blockage	Hemopneumothorax, rib fracture	Liver injury	Biliopleural fistula (treatment without thoracotomy)	No
25/(Yokosuka et al 2015)	78	M	Fall	Yes	CT/X-ray	Thoracoscopy and then mini-thoracotomy dual pleural adhesion – right side Removed without direct view of surgical blockage – left side	Pulmonary injury	–	n/c	No
26/(Chui et al 1998)	24	M	Fall	Yes	CT/X-ray/ aortography	Thoracotomy	Thoracic vertebral body fracture	–	n/c	No
27/(Edwin et al 2009)	22	F	Car accident	Yes	–	Thoracotomy	Hemopneumothorax, pulmonary laceration		n/c	No

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Patient/Reference	Age	Gender	Trauma mechanism	Hemodynamic stability on admission	Test performed	Treatment	Injuries found	Associated injuries	Complications	Death
28/(Edwin et al 2009)	18	F	Work accident	Yes	X-ray	Thoracotomy	Hemopneumothorax, ribs fractures, pulmonary contusion	–	Surgical wound infection, respiratory failure	No
29/(Grossi et al 1981)	18	M	Car accident	No	X-ray	Thoracotomy	Hemopneumothorax, pulmonary laceration, ribs fractures, intercostal vessels	–	n/c	No
30/(Pradhan et al 2012)	56	F	Fall	Yes	CT	Sternotomy	Hemothorax, heart laceration, pulmonary contusion, diaphragmatic injury	Liver injury	Surgical wound infection	No
31/(Wick 2001)	57	M	Fall	Yes	X-ray	Thoracotomy	Hemothorax, pulmonary injury	Limb fracture	n/c	No
32/(Bowley et al 2003)	40	M	Aircraft accident	No	X-ray	Thoracotomy	Pulmonary injury	–	n/c	No

Finally, 7 patients underwent direct removal of the penetrating object with thoracic drainage (1 patient being treated with the assistance of thoracoscopy on the right side and by direct removal on the left side).[1,6,14-16,18,24]

Most of the complications described were related to respiratory failure and surgical wound infection. Perioperative bleeding during the removal of the object occurred in two cases of thoracotomy and, in one case, after direct removal. In the latter case, the patient lost 500 mL of blood through the thoracic drain, and thoracotomy was not performed.[8,18] Conservative treatment was chosen, and the patient remained stable. Other complications on a smaller scale included sustained pulmonary fistula and necrosis of the chest wall.[1,16] One patient presented with the postoperative complication of abdominal compartment syndrome in an exclusively thoracic injury.[6] Another patient presented with a biliopleural fistula, which was treated with drainage and cholangiopancreatography.[18]

The underlying causes of the three deaths that occurred included sepsis due to surgical wound infection and empyema as well as respiratory failure due to lung injury with an inflammatory response to the trauma.[1,6,15]

Tomography, although recommended in stable patients, did not follow any standard, regardless of the type of injury sustained or the selected treatment. The use of tomography occurred pursuant to the choice of the individual surgeon, and the procedure was performed in only 37.5% of cases. Chest X-rays, in contrast, were performed in 65.62% of cases.

DISCUSSION

Penetrating chest wounds with retention of the impaled object are unusual. The literature is scarce, and there is a lack of recently published cases.[1,5] Therefore, the standard behavior of trauma services in response to this situation is exploratory thoracotomy to remove the impaled object.[14]

From the descriptive analysis of the included studies, it may be concluded that each patient has a different injury mechanism and, therefore, patients may require different treatments. This outcome can be observed in the cases describing removal of the object by means of thoracoscopy and/or even via direct removal without thoracotomy.[1,5,16,17]

This scenario requires new studies in order to provide surgeons with safe ways to treat this type of injury through other therapeutic possibilities beyond mere thoracotomy. Such evidence must reflect feasible treatments[5,17] that can be reproduced in trauma referral hospitals such that cases are well selected and the appropriate technological resources (e.g., CT, endoscopy and laparoscopic surgery) are available. In the case of treatment failure by thoracoscopy or direct removal, there is always the possibility of conversion to standard treatment, which is exploratory thoracotomy.

A proposed management protocol based on this literature review (summarized in flowchart found in Flow Chart 1) is as follows:

Initial Approach

The principles of Advanced Trauma Life Support (ATLS) should be respected upon primary assessment, namely, avoiding manipulation of the impaled object. If possible, the object's extremities should be cut to facilitate transport and to conduct imaging.[2,5,6,29]

The trauma mechanism should be considered. Blunt trauma with shrapnel can cause injuries to other body regions and transmit more energy than penetrating knife trauma.[2,4,30]

Requesting help from more experienced surgeons and other specialists (such as vascular and thoracic surgeons) should occur if necessary.[6] Passive observations should be avoided in favor of maintaining an ethical posture and supporting safety.[29]

Complementary Tests

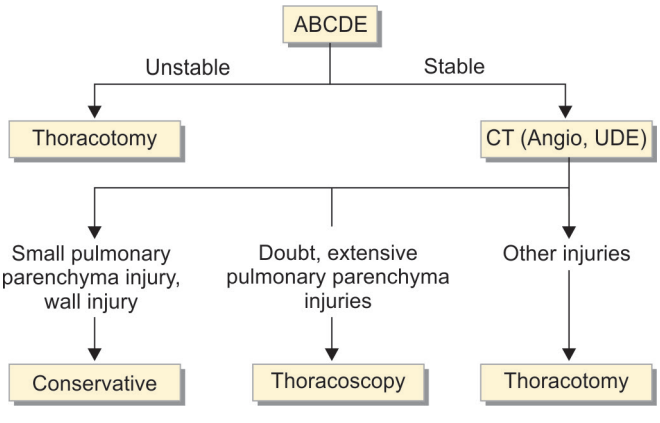
Tomography should always be considered as an imaging modality. This resource provides an important mechanism for identifying possible injuries in the stable patient and planning treatment.[5,6] Artefacts found upon imaging can be minimized through contrast reduction just as details can be reduced without affecting the diagnosis of critical injuries.[6]

The use of bronchoscopy, endoscopy, and angiography can follow if tomography reveals possible airway or gastrointestinal tract injury.[2,5]

Nonoperative Treatment (Direct Removal of the Object)

The first requirement is a stable patient.[5,31] The second requirement is that CT shows only pulmonary parenchymal injury (grade I or II) with a well-defined path.

Flow Chart 1: Proposed flowchart. ABCDE: ATLS protocol; CT: Computed tomography; UDE: Upper digestive endoscopy; Angio: Angiography



Direct removal must be performed in the operating room with the patient intubated, monitored, and prepared for possible exploratory thoracotomy. The affected hemithorax should be drained.[1,5]

Treatment by Thoracoscopy[14,16,17]

Thoracoscopy is indicated in stable patients with grade III pulmonary lesions. Thoracoscopy is safe (2% complication rate) and effective (only 0.8%) in treating unnoticed injuries.[32]

Treatment by Exploratory Thoracotomy

Exploratory thoracotomy is unquestionably the procedure of choice in an unstable patient.[30,31] Thoracotomy should be encouraged when there is doubt regarding a serious injury.[30,31]

Thoracotomy is also indicated when the patient has esophageal, primary airway, or large vessel injuries. Consider resuscitation thoracotomy for patients in extremis.[29]

Other Considerations

To prevent and combat sepsis, which is a significant complication related to this type of injury,[5] the following are suggested:

- Broad-spectrum empirical antibiotic therapy;[4,6]
- Debridement of the injury and thorough washing of the wound;[2,6,29] and
- Administration of tetanus immunoglobulin and a vaccine dose in all patients with indeterminate vaccination history.[2,4]

CONCLUSION

The review of case studies was limited. The literature suffers from a lack of significant sampling, and more cases with successful treatment are reported than cases with treatment failure. However, these initial studies are fundamental to the introduction of a new medical concept, especially in regards to unusual injuries.

This topic certainly merits revisiting as the experience level of trauma services increases. As advancements in diagnostic procedures are made, especially in regards to the latest generation of CT scanners, decreases in the use of thoracotomy in stable patients as well as in the incidence of inconclusive tests (and therefore unnoticed injury) can be anticipated.

CLINICAL SIGNIFICANCE

Following the recommendations listed in this study, some of which our institution has performed, can be expected to reduce the thoracotomy rate and thereby reduce mortality and benefit patients.

REFERENCES

1. Darbari A, Tandon S, Singh AK. Thoracic impalement injuries. Indian J Thorac Cardiovasc Surg 2005;21(3):229-231.
2. Thomson BN, Knight SR. Bilateral thoracoabdominal impalement: avoiding pitfalls in the management of impalement injuries. J Trauma 2000;49(6):1135-1137.
3. Bill JH. Notes on arrow wounds. Am J Med Sci 1862;40(88): 365-387.
4. Hyde MR, Schmidt CA, Jacobson JG, Vyhmeister EE, Laughlin LL. Impalement injuries to the thorax as a result of motor vehicle accidents. Ann Thorac Surg 1987 Feb;43(2): 189-190.
5. Sobnach S, Nicol A, Nathire H, Kahn D, Navsaria P. Management of the retained knife blade. World J Surg 2010 Jul;34(7): 1648-1652.
6. Davis IC, Davis JW, Groom T. Thoracic plank impalement: an engineering perspective. J Trauma 2003 May;54(5): 1036.
7. Shikata H, Tsuchishima S, Sakamoto S, Nagayoshi Y, Shono S, Nishizawa H, Watanabe Y, Matsubara J. Recovery of an impalement and transfixion chest injury by a reinforced steel bar. Ann Thorac Cardiovasc Surg 2001 Oct;7(5): 304-306.
8. Okumori M, Futamura A, Tsukuura T, Konno S, Kuramochi K, Kaya S, Yamada F. Impalement wounds of the head and chest by reinforced steel bars with recovery. J Trauma 1981 Mar;21(3):240-241.
9. Kaur K, Singhal S, Bhardwaj M, Kumar P. Penetrating abdomino-thoracic injury with an iron rod: an anaesthetic challenge. Indian J Anaesth 2014 Nov-Dec;58(6):742-745.
10. Chui W, Cheung D, Chiu S, Lee W, He G-W. A non-fatal impalement injury of the thorax. J R Coll Surg Edinb 1998 Dec;43(6):419-421.
11. Yokosuka T, Kobayashi T, Fujiogi M, Kawakami M, Yasuno M. An unusual case of thoracic impalement injury with severe pleural adhesion. Gen Thorac Cardiovasc Surg 2015 May;63(5):298-301.
12. Pradhan S, Sapkota R, Shrestha UK, Amatya R, Koirala B. Impalement injury to the heart. Kathmandu Univ Med J 2012 Jan-Mar;9(1):80-82.
13. Wick JM. Case report: survival of a type I transthoracic impalement. Int J Trauma Nurs 2001 Jul-Sep;7(3):88-92.
14. Burack JH, Amulraj EA, O'Neill P, Brevetti G, Lowery RC. Thoracoscopic removal of a knife impaled in the chest. J Thorac Cardiovasc Surg 2005 Oct;130(4):1213-1214.
15. Frangos SG, Ben-Arie E, Bernstein MP, Miglietta MA. Thoracic stab wound with impaled knife. J Trauma 2006 Jun;60(6):1379.
16. Williams CG, Haut ER, Ouyang H, Riall TS, Makary M, Efron DT, Cornwell EE 3rd. Video-assisted thoracic surgery removal of foreign bodies after penetrating chest trauma. J Am Coll Surg 2006 May;202(5):848-852.
17. Bar I, Rivkind A, Deeb M, Simha M. Thoracoscopically guided extraction of an embedded knife from the chest. J Trauma 1998 Jan;44(1):222-223.
18. Lunevicius R, O'Sullivan A. Unusual management of thoracoabdominal impalement injury to the right hemiliver and diaphragm. Chin J Traumatol 2014;17(1):41-43.
19. Cartwright AJ, Taams KO, Unsworth-White MJ, Mahmood N, Murphy PM. Suicidal nonfatal impalement injury of the thorax. Ann Thorac Surg 2001 Oct;72(4):1364-1366.
20. Ruano RM, Pereira BM, Biazzoto G, Bortoto JB, Fraga GP. Management of severe thoracic impalement trauma against two-wheeled horse carriage: a case report and literature review. Indian J Surg 2014 Aug;76(4):297-302.
21. Davies RS, Wall ML, Abdelhamid M, Vohra RK. Computed tomography directed surgical treatment for thoracoabdominal impalement injury. Injury Extra 2009;40(5):96-98.
22. Edwin F, Tettey M, Sereboe L, Aniteye L, Kotei D, Tamatey M, Entsuamensah K, Delia I, Frimpong-Boateng K. Impalement injuries of the chest. Ghana Med J 2009 Jun;43(2):86-89.
23. Grossi A, Mezzacapo B, Biagi G, Gotti G. Impalement wound of the chest. Thorax 1981 Dec;36(12):952-953.
24. Bowley DM, Gordon MP, Boffard KD. Thoracic impalement after ultralight aircraft crash. J Thorac Cardiovasc Surg 2003 Apr;125(4):954-955.
25. Mathur R, Devgarha S, Goyal G, Sharma D. Impalement injury involving both heart and lung: a rare case report. IOSR J Dent Med Sci 2013;9(4):62-65.
26. Wimalachandra WS, Asmat A. Mediastinal impalement with a fibreglass sheet. Singapore Med J 2014 Sep;55(09):e148-e149.
27. Fradet G, Nelems B, Müller NL. Penetrating injury of the torso with impalement of the thoracic aorta: preoperative value of the computed tomographic scan. Ann Thorac Surg 1988 Jun;45(6):680-681.
28. Shimokawa S, Shiota K, Ogata S, Toyohira H, Moriyama Y, Taira A. Impalement injury of the thorax: report of a case. Jpn J Surg 1994;24(10):926-928.
29. Horowitz MD, Dove DB, Eismont FJ, Green BA. Impalement injuries. J Trauma 1985 Sep;25(9):914-916.
30. Romero L, Nagamia H, Lefemine A, Foster E, Wysocki J, Berger R. Massive impalement wound of the chest. A case report. J Thorac Cardiovasc Surg 1978 Jun;75(6):832-835.
31. Kelly IP, Attwood SE, Quilan W, Fox MJ. The management of impalement injury. Injury 1995 Apr;26(3):191-193.
32. Villavicencio RT, Aucar JA, Wall MJ. Analysis of thoracoscopy in trauma. Surg Endosc 1999 Jan;13(1):3-9.