

Abdominal Gunshot Wounds: A Narrative Review of Hunterian Principles and Contemporary Management

Introduction

Abdominal injury from gunshot wounds (GSWs) represents a significant proportion of those injured in modern conflicts (19.5%).^[1-2] Today, the mortality rate from isolated abdominal GSWs is reported to be 10%.^[3] This represents a significant reduction (90%) when compared to the mortality rate encountered by John Hunter and his contemporaries, where penetrating abdominal GSWs were considered to be a terminal injury.

Hunter (1728-1793) was a prominent 18th century anatomist, scientist, and Surgeon-General of the British Armed Forces.^[4] Hunter contributed to the establishment of the surgical profession as a dignified scientific discipline by advocating for an evidence-based approach to medicine through observation and experiment.^[5] Hunter considered that GSWs were “*increasingly becoming a specialty in their own right*”.^[6] As such, he included an in-depth discussion on the management of abdominal GSWs in his seminal work *A Treatise on the Blood, Inflammation, and Gun-Shot Wounds*.^[6] This historical narrative will explore Hunter’s contributions to the management of abdominal GSWs in the context of the 18th and 19th century discourse, compared to contemporary management.

The Mechanism of Injury of Abdominal GSWs

In 1730,^[7] the British Army introduced a revolutionary weapon system into service that would change the nature of battlefield injuries forever: the flintlock musket. This weapon fired lead balls which would cause significant injuries at close range (*Figure 1 & 3*). Prior to this, the most prevalent penetrating injury patterns were caused by bladed weapons and arrow heads.

Hunter’s contribution to the management and documentation of these new types of wounds recognised the importance of considering the mechanism of the injury. Hunter broadly divided GSWs into two categories; simple (where “*the ball passes through the soft parts [of the body] only*”) and compound (where “*other parts [are] wounded*”).^[6] Hunter took the view that “*very few wounds...require[d] surgical treatment at their commencement*.”^[6] Therefore, he advocated for a conservative approach to the management of GSWs.



Figure 1 Lead musket balls 16mm in diameter.^[8]

Since the 18th century, technology driven advances in weapon lethality have yielded more severe and complex injury patterns in modern conflicts compared to

those encountered by Hunter. It is important to consider how the passage of time has changed the injury patterns resulting from GSWs to enable the valid comparison of historical and contemporary surgical techniques. Furthermore, appreciation should be given to the fact that musket balls and modern bullets (*Figure 2*) are very different projectiles.

Several factors influence the energy of a projectile, which is inextricably linked to the severity of tissue injury sustained in a GSW. The major determinant of energy transfer is the speed of the projectile^[10] (*Figure 3*). Musket balls travel at significantly slower velocities before impact (400 metres per second) when compared to modern bullets (940 metres per second).^[11] Further, the mass of a musket ball is much heavier compared to a modern bullet. However, the increase in kinetic energy is not influenced by the same magnitude as increases in velocity, which is raised to the power of two (see the formula in *Figure 3*). The shape of a modern bullet is sharper and will penetrate deeper into tissue when compared to a round musket ball, which will underpenetrate.

Hunter correctly identified that musket balls of higher velocity will tend to cut tissue surgically.^[6] When the velocity is lower, the path of the ball will be less predictable causing blood vessels to tear and contusion to form.^[6] The above analysis demonstrates that the ballistic characteristics of a musket ball are generally less violent compared to modern high-velocity bullets. This provides a strong argument for the appropriateness of Hunter's surgically conservative approach to the management of abdominal GSWs. This is because deep structures were less likely to be injured. As explored below, the surgical management of abdominal GSW remained elusive until the late 19th century.



Figure 2 Modern bullet 5.56mm in diameter.
Left to right: Bullet, case and complete cartridge.^[9]

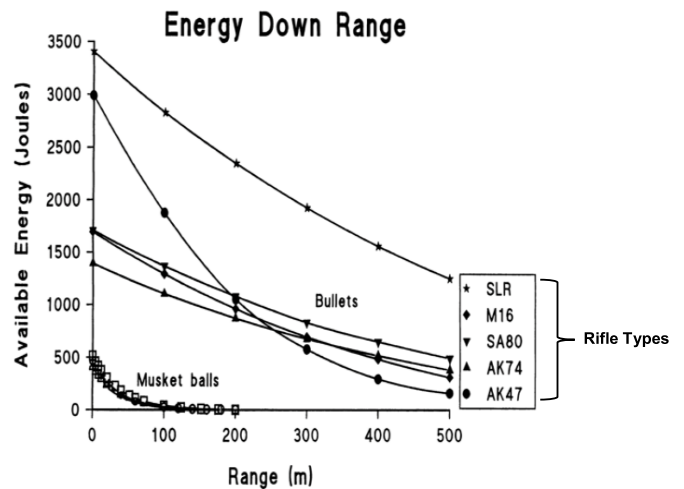


Figure 3 Energy of musket balls compared to modern bullets at different ranges.^[11]

The **SA80** is the current British Army rifle.

$$\text{Kinetic Energy}^{[10]} = \frac{1}{2} \cdot \text{Mass} \cdot \text{Velocity}^2$$

Hunter's Surgically Conservative Approach

Hunter's attitude towards the management of abdominal GSWs was one of surgical conservatism. Through conducting experiments on animals and autopsies in humans, Hunter observed that when wounded "*intestines [would] connect by adhesion[s] in several places.*"^[6] He interpreted this as evidence that the intestine had self-sealing properties, thereby closing any perforation through the process of adhesive inflammation. Therefore, he took the view that the most appropriate course of action was "*to be very quiet and do nothing*"^[6] in cases of intestinal perforation following an abdominal GSW.

Hunter's surgical conservatism and evidence-based approach is further demonstrated by a case report he wrote regarding a patient who died following an abdominal GSW in 1783. Hunter viewed "*operative surgery as a mutilation of the patient and an admission of failure to cure by more physiological means.*"^[12] Favoured approaches used by Hunter included tepid baths, tobacco smoke enemas, willow bark, bloodletting and morphine.^[6] Bloodletting was the name given to the removal of blood from a vein as a therapeutic procedure. Hunter practised bloodletting judiciously, as he understood that "*it [could] kill.*"^[6] Therefore, he determined that its use should only be considered in patients with an imbalance of blood; either where the patient "*make[s] too much blood, or cannot bear the usual quantity [of blood].*"^[6] Smoke enemas were believed to act as a stimulant, and bark was recommended by Hunter to "*strengthen, regulate the system, and [act as] an antispasmodic.*"^[6]

On the pharmacodynamics of bloodletting and bark, Hunter believed reducing the circulatory volume of blood would reduce the strain on the heart and "*lessen [the severity of] the inflammation,*"^[6] whilst the addition of bark would complement as an anti-inflammatory. Willow tree bark contains salicin,^[13] which is similar in composition to non-steroidal anti-inflammatory drugs.

Hunter's belief that bloodletting would ease the metabolic demand of the heart was intuitive but flawed. Peritonitis following hollow viscus injury from an abdominal GSW would lead to septic shock. Bloodletting would be detrimental in the shocked patient, reducing intravascular blood volume, contributing to organ hypoperfusion.^[14] The modern approach to resuscitation described by the *Surviving Sepsis Campaign* places an increased emphasis on liberal intravenous fluid therapy volumes in patients with septic shock, with the goal of maintaining organ perfusion.^[14]

The management of abdominal GSWs left surgeons of the 18th and 19th century with a difficult conundrum; surgically conservative approaches such as those adopted by Hunter were associated with a high mortality rate. Yet interventionist approaches were associated with a near 100% mortality rate. In the circumstances, Hunter's surgically conservative approach was appropriate considering the surgical environment of the time.

Early 19th Century Abdominal Surgery

The year before Hunter died in 1792,^[15] Europe was once again at war, culminating in the Battle of Waterloo in 1815. Hunter's legacy remained topical in the surgical literature of the early 19th century. George Guthrie (1785-1856), the principal surgeon to the Duke of Wellington,^[16] revered Hunter's contribution to surgical advancement. However, he scrutinised some of Hunter's approaches: "*Mr. Hunter...laid the foundation for a practice equally, if not more dangerous...that of neglecting dilatation [of GSWs] under circumstances in which it was absolutely necessary*".^[16] Although Guthrie identified flaws in Hunter's approach to the management of abdominal GSWs, he too was unable to provide an infallible solution to their treatment.

Half a century later, two watershed moments provided the rate-limiting steps to facilitate the advancement of abdominal surgery. The first was reliable general anaesthesia, which was performed using the inhalation agent ether in 1846.^[17] The second was asepsis, pioneered by Sir Joseph Lister in 1867.^[18] General anaesthesia and asepsis during abdominal surgery are essential for optimal surgical conditions and favourable patient outcomes. However, neuromuscular blocking drugs used in anaesthesia were not synthesised until 1947.^[19] As a result, anaesthetists in the 19th century were obligated to deeply anaesthetise patients undergoing major surgery to reduce the muscle tone of the abdominal wall. This allowed surgeons to incise through the deep tissue layers in order to gain access to the abdominal cavity. The deep plane of anaesthesia would detrimentally affect anaesthetised patients' cardiovascular system, which, in the shocked patient, could prove to be fatal. The biggest determinant of survival for the patient undergoing abdominal surgery was speed of surgery and reduced time under anaesthesia,^[20] indicating the technique required further refinement.

The Catalysts for Surgical Innovation

William MacCormac (1836-1901) was a prominent British surgeon; like Hunter, he practised in the military and civilian sectors. MacCormac strongly advocated for prophylactic asepsis and strict hygiene during surgery. He viewed "*exploratory abdominal [surgery]*"^[20] as valuable in affording a patient "*the only possible means of rescue*"^[20] follow an abdominal GSW. MacCormac rightly recognised that where a patient had sustained an intestinal perforation from a bullet, a delay to operate would invariably lead to "*peritonitis, shock*"^[20] and death.

MacCormac was progressive for his time, publishing an innovative technique to resect damaged sections of small bowel by forming an anastomosis between the two healthy ends using interrupted sutures of "*fine cat gut*".^[20] He advocated for folding rather than resecting the redundant mesentery to negate the risk of avascular necrosis at the anastomosis site (*Figure 4*). In this way, MacCormac significantly contributed to the advancement of abdominal surgery, with his techniques bearing similarities to how surgery on the bowel is practised today.

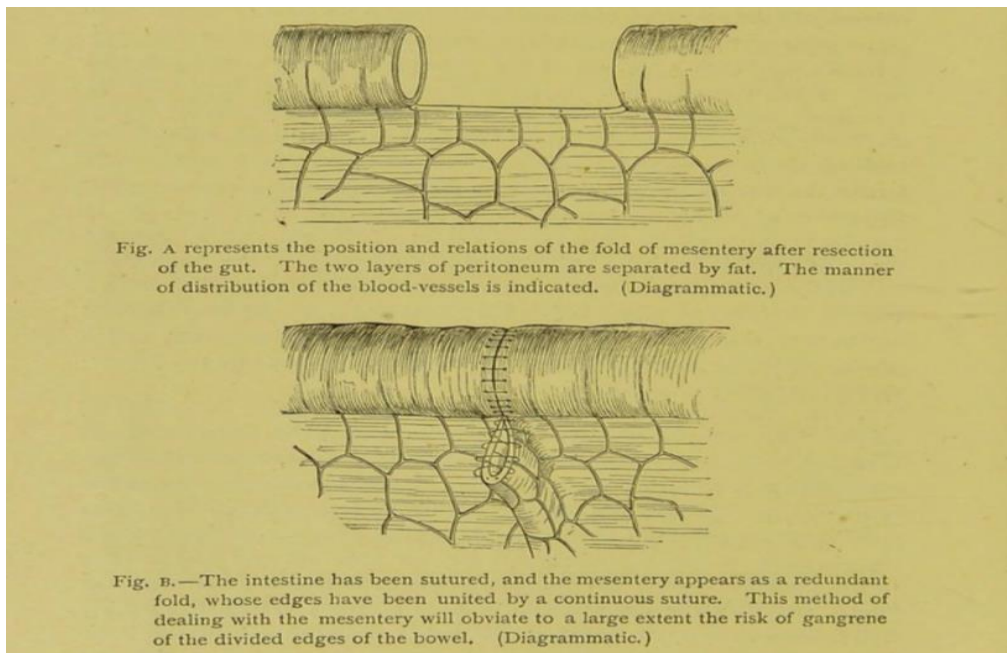


Figure 4 Illustration taken from *On abdominal section for the treatment of intra-peritoneal injury*, 1887.^[20]

Contemporary Management of GSWs

Little debate exists as to the indication for mandatory abdominal exploration through laparotomy (see 'A' in *Figure 5*).^[3,21-23] Non-operative approaches have been refined in recent decades by introducing a policy of selective non-operative management (SNOM) for a stable cohort of patients identified by clinical evaluation and diagnostic investigations (*Figure 5*).^[3,24-25] The two most common subgroups of patients who are appropriate for SNOM are those in which the bullet has not passed through any critical structures, or those with an isolated penetrating injury to a solid organ (liver, kidney, spleen).^[3] SNOM can be considered as a return to the Hunterian principle of conservatism, catalysed by advances in cross-sectional imaging to facilitate triage and surgical planning.^[21,26] Clinicians no longer need to, as Hunter once said, wait "*till the deadened part has separated...to know what parts [of the organ or tissue] are killed.*"^[6] Computer-tomography (CT) can diagnose pathology with high levels of sensitivity and specificity. These innovations have enabled clinicians to identify where surgical intervention can be avoided. Prior to CT, the rate of negative laparotomy (where no pathological findings can be identified) was high, at 40%.^[27] A 2013 international survey^[28] investigating the practise of SNOM at trauma centres in the context of abdominal GSWs reported a significantly reduced negative laparotomy rate (8.6-14%).^[29-30] Therefore, a SNOM approach in abdominal GSWs resonates with the Hunterian principle of evidence-based surgical conservatism.

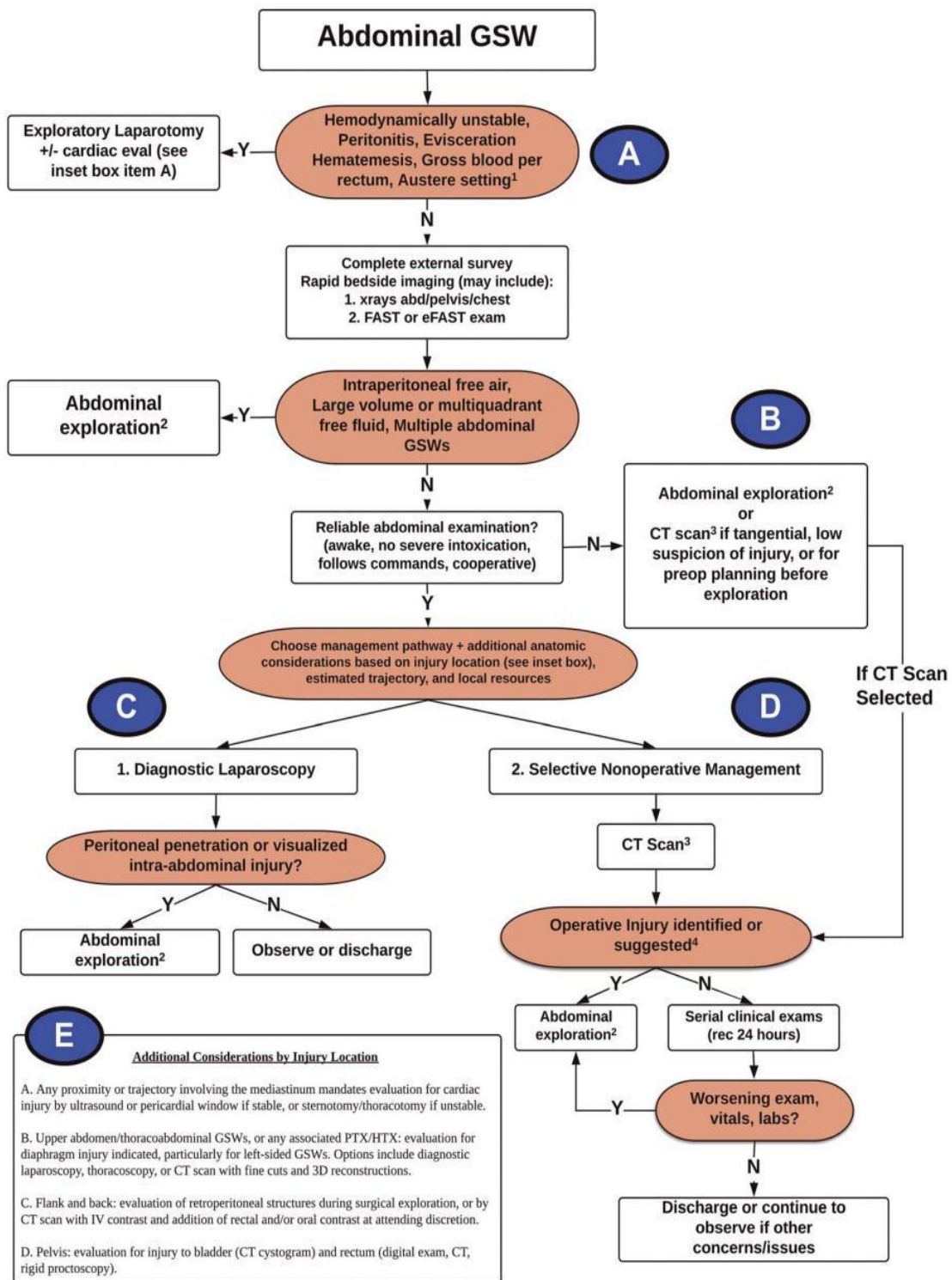


Figure 5 Western trauma association algorithm for the evaluation and management of patients with abdominal gunshot wounds.^[3]

Conclusion

Hunter's determination to develop surgery through meticulous observation and experiment remains central to his legacy. Hunter was correct (possibly by coincidence) in his observation that it is appropriate to avoid surgical intervention in certain cases of abdominal GSWs, indicated by the emergence of surgical conservatism through SNOM.

In *The Life of John Hunter*, Ottley describes "*boldness and interdependence in the pursuit of truth...[as] one of the striking characteristics of Hunter's mind.*"^[31] Indeed, Hunter advocated for an evidence-based approach to the advancement of scientific knowledge, which influenced future generations to challenge the status quo of archaic surgical doctrine, in the pursuit of fact. Hunter reinforced this idea in his students; "*[n]ever ask me what I have said or what I have written; but if you will ask me what my present opinions are, I will tell you.*"^[31] This emphasis on continual surgical development, advocated for by Hunter, has supported future generations of students to evaluate Hunter's findings and codify his most useful insights. This has enabled them to use the relevant lessons to educate, inform and reflect on their own surgical practise.

References

- 1 Annual deaths from the WHO Global Health Observatory (2018). *Injuries and Violence*. <https://www.who.int/news-room/fact-sheets/detail/injuries-and-violence>. [Accessed 20th November 2023].
- 2 Ramasamy A, Harrisson SE, Stewart MP, Midwinter M. Penetrating missile injuries during the Iraqi insurgency. *The Annals of The Royal College of Surgeons of England*. 2009;91(7):551-8.
- 3 Martin MJ, Brown CV, Shatz DV, Alam H, Brasel K, Hauser CJ, de Moya M, Moore EE, Vercruyse G, Inaba K. Evaluation and management of abdominal gunshot wounds: A Western Trauma Association critical decisions algorithm. *Journal of Trauma and Acute Care Surgery*. 2019;87(5):1220-7.
- 4 Major HAL Howell. John Hunter F.R.S Surgeon-General and Inspector-General of Hospitals. Reprinted from the *journal of the Royal Army Medical Corp*. 1912;19(2):144-50. [Accessed 27 Sept 23 from The Museum of Military Medicine Library & Archive, Keogh Barracks, Ash Vale, Aldershot, England, GU12 5RQ].
- 5 Editors of Encyclopaedia Britannica. *John Hunter British surgeon*. <https://www.britannica.com/biography/John-Hunter-British-surgeon>. [Accessed 12th October 2023].
- 6 John Hunter. *A treatise on the blood, inflammation, and gun-shot wounds*. London: Sherwood, Gilbert & Piper; 1828. <https://wellcomecollection.org/works/b738mpgb>.
- 7 Alistair Macmillan. *A Contextual Chronology of the Army Medical Services Since the forming of the Standing Army in 1660 to 2020*. Renfrewshire, Scotland 2021. [Accessed 27 Sept 23 from The Museum of Military Medicine Library & Archive, Keogh Barracks, Ash Vale, Aldershot, England, GU12 5RQ].
- 8 National Maritime Museum, Greenwich, London. *Eleven lead musket balls*. <https://www.rmg.co.uk/collections/objects/rmgc-object-2123>. [Accessed 9th November 2023].
- 9 MOD Crown Copyright. (2023). *Small Arms and Support Weapons*. Army <https://www.army.mod.uk/equipment/small-arms-and-support-weapons>. [Accessed 4th October 2023].
- 10 Shin EH, Sabino JM, Nanos III GP, Valerio IL. Ballistic trauma: lessons learned from Iraq and Afghanistan. *In Seminars in plastic surgery* 2015;29(1):10-9.
- 11 Craig RP. Gunshot wounds then and now: how did John Hunter get away with it?. *The Annals of The Royal College of Surgeons of England*. 1995; Spec No:15-9.
- 12 Ellis H. John Hunter's teachings on gunshot wounds. *Journal of the Royal Society of Medicine*. 2001;94(1):43-5.

- 13 Oketch-Rabah HA, Marles RJ, Jordan SA, Dog TL. United States pharmacopeia safety review of Willow Bark. *Planta medica*. 2019;85(16):1192-202.
- 14 Evans L, Rhodes A, Alhazzani W, Antonelli M, Coopersmith CM, French C, Machado FR, Mcintyre L, Ostermann M, Prescott HC, Schorr C. Surviving sepsis campaign: international guidelines for management of sepsis and septic shock 2021. *Critical care medicine*. 2021;49(11):1063-143.
- 15 Kapp KA, Talboy GE, Kapp K. John Hunter, the father of scientific surgery. *Bulletin of the Surgical History Group, papers from the American College of Surgeons*. 2017:34-41.
- 16 Guthrie GJ. *A Treatise on Gun-shot Wounds*, 3rd edn, London: Burgess and Hill; 1827. <https://wellcomecollection.org/works/utckgvu3>.
- 17 Bigelow HJ. Insensibility during surgical operations produced by inhalation. *The Boston medical and surgical journal*. 1846;35(16):309-17.
- 18 Bonnin JG, LeFanu WR. Joseph Lister 1827-1912: a bibliographical biography. *The Journal of Bone and Joint Surgery. British volume*. 1967;49(1):4-23.
- 19 Dorkins HR. Suxamethonium-the development of a modern drug from 1906 to the present day. *Medical History*. 1982;26(2):145-68.
- 20 William MacCormac. *On abdominal section for the treatment of intra-peritoneal injury*. London: Ballantyne, Hanson; 1887. <https://wellcomecollection.org/works/ms8e7yep>.
- 21 Biffi WL, Leppaniemi A. Management guidelines for penetrating abdominal trauma. *World journal of surgery*. 2015;39:1373-80.
- 22 Demetriades D, Hadjizacharia P, Constantinou C, Brown C, Inaba K, Rhee P, Salim A. Selective nonoperative management of penetrating abdominal solid organ injuries. *Annals of surgery*. 2006;244(4):620.
- 23 Salim A, Velmahos GC. When to operate on abdominal gunshot wounds. *Scandinavian journal of surgery*. 2002;91(1):62-6.
- 24 Inaba K, Demetriades D. The nonoperative management of penetrating abdominal trauma. *Advances in surgery*. 2007;41:51-62.
- 25 Stawicki SP. Trends in nonoperative management of traumatic injuries-A synopsis. *International journal of critical illness and injury science*. 2017;7(1):38.
- 26 Como JJ, Bokhari F, Chiu WC, Duane TM, Holevar MR, Tandoh MA, Ivatury RR, Scalea TM. Practice management guidelines for selective nonoperative management of penetrating abdominal trauma. *Journal of Trauma and Acute Care Surgery*. 2010;68(3):721-33.

27 Demetriades D, Velmahos G. Technology-driven triage of abdominal trauma: The emerging era of nonoperative management. *Annual Review of Medicine*. 2003;54:1-15.

28 Jansen JO, Inaba K, Resnick S, Fraga GP, Starling SV, Rizoli SB, Boffard KD, Demetriades D. Selective non-operative management of abdominal gunshot wounds: survey of practise. *Injury*. 2013;44(5):639-44.

29 Demetriades D, Velmahos G, Cornwell E, 3rd, Berne TV, Cober S, Bhasin PS, et al. Selective nonoperative management of gunshot wounds of the anterior abdomen. *Archive of Surgery*. 1997;132:178-83.

30 Velmahos GC, Demetriades D, Toutouzas KG, Sarkisyan G, Chan LS, Ishak R, et al. Selective nonoperative management in 1,856 patients with abdominal gunshot wounds: Should routine laparotomy still be the standard of care? *Annals of Surgery*. 2001;234:395-402.

31 Ottley, Drewry. *The works of John Hunter, F.R.S. with notes*. London: Longman, Rees, Orme, Brown, Green, and Longman;1835.
<https://wellcomecollection.org/works/hhppjbrb>.