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Performance of primary repair on colon injuries sustained from low-versus high-energy projectiles

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ABSTRACT

Among various reasons, colon injuries may be caused by low- or high-energy firearm bullets, with the latter producing a temporary cavitation phenomenon. The available treatment options include primary repair and two-stage management, but recent studies have shown that primary repair can be widely used with a high success rate. This paper investigates the differences in performance of primary repair on these two types of colon injuries. Two groups of patients who sustained colon injuries due to single gunshot wounds, were retrospectively categorized based on the type of bullet. Primary colon repair was performed in all patients selected based on the inclusion and exclusion criteria (Stone and Fabian's criteria). An almost absolute homogeneity was attained among the groups in terms of age, latent time before surgery, and four trauma indexes. Only one patient from the low-energy firearm projectile group (4%) developed a postsurgical complication versus nine patients (25.8%) from the high-energy group, showing statistically significant difference ($p = 0.03$). These nine patients experienced the following postsurgical complications: pneumonia, abscess, fistula, suture leakage, and one multiorgan failure with sepsis. Previous studies concluded that one-stage primary repair is the best treatment option for colon injuries. However, terminal ballistics testing determined the projectile's path through the body and revealed that low-energy projectiles caused considerably lesser damage than their high-energy counterparts. Primary colon repair must be performed definitely for low-energy short firearm injuries but very carefully for high-energy injuries. Given these findings, we suggest that the treatment option should be determined based not only on the bullet type alone but also on other clinical findings.

1. Introduction

The colon is the second most commonly injured intra-abdominal organ in cases of penetrating trauma.[1] Although colon trauma is highly prevalent, it can be difficult to identify as different factors influence its origin.[2] Fatal penetrating colon injuries are typically caused by firearm bullets, as well as by stabbing with sharp weapons. The mortality rate from gunshot injuries of the colon ranges from 3% to 16%.[3] Early death due to penetrating colon trauma is linked to severe bleeding and exsanguination, whereas delayed death is linked to sepsis and multiorganic insufficiency.[4] In the late postoperative period, other factors may lead to death, such as abscesses, fistulas, and/or leakage of the anastomosis or even the abdominal wall.[5]

Due to its complexity, the management of penetrating colon trauma has been extensively studied. The available treatment options include primary repair and various types of two-stage management (e.g., fecal diversion). However, the specific procedures to be used in different cases are still debatable.[6–9] Relevant studies describe several factors that influence prognosis: site of injury, degree of tissue destruction, presence of multiple and/or multisegmentational injuries, number of simultaneous injuries of other organs, time elapsed from injury to surgery, development of shock, fecal contamination, and bowel devitalization. The treatment option should be chosen based on these factors.[1,10–13]

A few methods are available to determine the severity of colon injuries. Apart from universal methods, such as the Revised Trauma Score (RTS) and Injury Severity Score (ISS), other more specific

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methods are used to assess abdominal trauma: the Penetrating Abdominal Trauma Index (PATI), the Flint scale, and Stone and Fabian's criteria (S/F) for primary repair of colon injury.

The nature of gunshot wounds varies considerably based on the type of firearm causing the injury. Firearms can be broadly categorized as follows: those with long barrels, including shotguns and rifles (the smooth-bore weapon, and single-shot, bolt-loaded, and self-loading rifles), and those with short barrels, commonly known as handguns including pistols and revolvers.[14] Shotguns and handguns fire low-velocity projectiles, whereas many rifles fire high-velocity projectiles. The higher the velocity the greater the kinetic energy transfer to the human body. This significant transfer of energy causes temporary cavitation, wherein the tissue stretches radially due to a shock-wave effect. This can cause remote injuries beyond the permanent wound cavity. A missile's ability to produce a temporary cavity is considered an important aspect of wound severity and the degree of damage caused.[15,16] When a missile enters the body, kinetic energy is imparted to the surrounding tissues, which forces the molecules of the tissues adjacent to the track to move centrifugally outwards even after the missile has traveled forward.[14] The temporary cavity may be considerably larger than the diameter of the bullet, lasting for a few milliseconds before collapsing into the permanent cavity or wound – bullet track. Ragsdale and Josselson argued that short-barreled firearms also produce some degree of cavitation, but not as much as rifle guns.[17] In addition to energy, momentum, mass, and bullet shape also affect wound severity.

This paper investigates the differences in the performance of primary repair of colon injuries based on two different types of projectiles: low energy and high energy. The energy of the missiles will affect the projectile path through the body and the extent of temporary cavitation.

2. Material and methods

During the last 25 years (1990–2015), 250 patients were admitted to the Clinical Center of Montenegro with penetrating abdominal injury. Of these patients, only those who sustained a single gunshot wound injuring the colon and no more than two other injured abdominal organs were selected for primary colon repair. Sixty patients were identified, all of whom were male. They were divided into two groups based on the type of projectile: low energy (group 1) and high energy (group 2). As both the appearance of the entrance wound and any other forensic characteristic (except shotgun pellets) are not good predictors of the type of weapon, low- and high-energy projectiles were differentiated based on the type and caliber of the bullet found in the body preoperatively (computed tomography (CT), multislice computed tomography (MSCT), and ultrasound) or intraoperatively, along with the police investigation files related to the type of weapon used (especially for cases with an exit wound). Along with forensic investigation, the weapon used was determined using a reliable method and the patients were grouped, as the caliber and appearance of the bullet (retained within the body or found at the crime scene) were submitted for expert forensic ballistics analysis and these characteristics determined. In this study, only data from patients injured by a firearm could be confirmed.

In all 60 patients, one-stage primary surgical repair was performed, which included a direct suture or a resection with primary anastomosis, namely primary suture of the colon or the rectum, right hemicolectomy, left flexure resection, left hemicolectomy, and transverse colon resection with termino-terminal anastomosis.

The exclusion criteria for primary repair were related to three or more S/F criteria[18]: presence of shock at admission to the hospital (blood pressure < 90 mmHg); injury of two or more abdominal organs; signs of exsanguination (hemoglobin <90); >750 ml of blood in the peritoneal cavity; presence of peritonitis as an absolute contraindication; time elapsed from injury >8 h; or concomitant injuries of the thorax, head, large blood vessel, or large defect of the abdominal wall. Furthermore, injuries sustained from smooth-bore shotgun were excluded from the study. Injuries due to revolvers were also excluded, as the projectiles of some revolvers, such as 357 Magnum, transfer very high energy to the body, but still far lower than the rifle projectiles. To avoid confusion, we decided to exclude all revolvers from the study.

Critically ill patients were not selected, and the concept of surgery as damage control was used only in a limited manner.[19]

Three indexes were calculated in order to compare the groups: RTS, ISS, and PATI.

The RTS is a trauma scoring system, with high inter-rater reliability and high accuracy in predicting death. It is scored using the first set of data obtained on the patient. It comprises items such as the Glasgow Coma Scale (GCS), systolic blood pressure (SBP), and respiratory rate (RR). The RTS is defined by the following equation: $RTS = 0.9368\ GCS + 0.7326\ SBP + 0.2908\ RR$.[20]

ISS standardizes the severity of traumatic injury based on the worst injury of six body systems, ranging from 3 to 75, with 75 indicating an “unsurvivable” condition.[21]

PATI was developed in 1981 and was used to identify trauma patients with the risk of postoperative complications.[22] PATI has been used to measure injury severity in penetrating abdominal trauma to help surgeons categorize patients based on the risk of developing complications, and prioritize the repair of intra-abdominal organs according to the severity score.[23] The PATI score examines 14 organs and assigns a risk factor to each organ, graded by severity ranging from 1 for minimal injury to 5 for maximal injury. The severity grade is multiplied by the risk factor for each of the 14 organs. The sum of this quantity for all injured organs constitutes the PATI. The rate of postoperative complications increases sharply if the PATI >25.[22]

Along with the S/F exclusion criteria, TS, ISS, and PATI, the Flint scaling was also used in all patients admitted to the hospital. In 1981, Flint suggested a classification for determining the mortality level of colon injuries based on three grades[24]:

- Grade 1 (mortality 4%) indicates isolated colon injury with minimal contamination, which is treated by primary repair or right colectomy with primary anastomosis indicated.
- Grade 2 (mortality 20%) indicates the presence of entrance and exit wounds, moderate contamination with no more than two other organs injured, and minimal shock, which is treated by exteriorization with secondary repair, or mucosal fistula if the rectum or the descendent colon is injured.
- Grade 3 (mortality 25%) indicates severe tissue injury, devascularization, severe contamination, and shock with multiorgan injuries, which is treated similarly to grade 2, accompanied by lavage, extensive debridement, and remain injury unsutured.

Patients with Flint Grade 2 and 3 injuries were excluded from the study.

The success of primary repair is defined as complete restitution of the patient without the development of any postsurgical complication such as sepsis, abscess formation, fistulas, leakage of anastomosis, infection, pneumonia, or any other condition that leads to re-laparotomy. Every patient was followed up routinely, with daily laboratory examination of blood parameters, measurement of temperature, and cleaning of wounds, followed by monitoring of drainage volume and radiographic and ultrasonographic examination if needed. Primary repair also included antibiotic prophylaxis with third generation of cephalosporins and