Management of Blunt Trauma to the Spleen (Part 1)

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Abstract

Spleen is the most frequent solid organ to be injured in blunt abdominal trauma. Considering its important role in providing immunity and preventing infection by a variety of mechanisms, every attempt should be made, if possible, to salvage the traumatized spleen at any age particularly in children. After primary resuscitation, mandatory requirements for non-operative management include absence of homodynamic instability, lack of associated major organ injury, admission in the intensive care unit for high-grade splenic injury and in the ward for milder types with close monitoring. About two third of the patients would respond to non-operative management. In most patients, failure of non-operative measures usually occur within 12 hours of management. Determinant role of abdominal sonography or computed tomography, and in selected cases, diagnostic peritoneal lavage, for appropriate decision cannot be overemphasized. However, the high status of clinical judgment would not be replaced by any paraclinical investigations. When operation is unavoidable, if possible, spleen saving procedures (splenorrhaphy or partial splenectomy) should be tried. In case of total splenectomy, auto-transplantation, preferably in the omental pouch, may lead to return of immunity, at least partially, to prevent or reduce the chance of subsequent infection. Although total splenectomy with autograft is immunologically superior to total splenectomy-only procedure, these patients should also be protected by vaccination and daily antibiotic for certain period of time. The essential steps for prevention of overwhelming infection after total splenectomy are not only immunization and administration of daily antibiotic (up to 5 years of age or one year in older children), but include education and information about this dangerous complication. When non-operative management is successful, the duration of activity restriction (in weeks) is almost equal to the grade of splenic injury plus 2.
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Keywords ● Trauma ● spleen ● autograft ● Infection ● non-operative management

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Introduction

The word spleeny, an adjective related to the spleen, means ill-tempered, hot-tempered, immoral, or irascible as this organ was thought to be the site of conflicting emotions or, according to Hippocrates, source of black bile, causing subsequently immorality and ultimately melancholy. It was also thought that the spleen aids in digestion and regulates

the soul. Aristotle thought there was no function for the spleen, while Galen believed that the spleen was an organ full of mystery. Galen in the second century (130-200 AD), stated that "the spleen must be looked upon as the great blood filter, purifying the blood in its passage by taking up the particles of foreign matter".[1] He also thought that this organ was the source of good mood or a location for filtering humor from the blood or liver.[1] Although, unlike many other organs such as brain, heart, lung, and liver, the spleen is not essential to life, by comprising 25% of the body lymphoid mass, the spleen is the most important organ to provide immunity.

In blunt abdominal trauma, among the solid organs, the liver and spleen are the two most frequent organs prone to injury. Till few decades ago, management of splenic injury was total splenectomy, as there was a wrong belief that once the spleen is injured, it will be eventually ruptured. Therefore, most surgeons believed that conservative therapy would be futile, dangerous, and even fatal. In other words, owing to wrong belief that preservation of an already injured or lacerated spleen would be impossible and life threatening, total splenectomy was the only option. Several decades before universal emphasis on detrimental effects of asplenia, increased susceptibility to infection in the absence of the spleen and its importance in resistance to infection were explained by Morris and Bullock in 1919.[3] O'Donnell was the first to report post-splenectomy infection in a child in 1929.[4] In 1952, King and Schumacker reported five infants who developed septicemia within three years after total splenectomy for spherocytosis.[5] After which, more attention was made on the relation of the spleen and the chance of infection and also its positive effects on quality of life. For this reason, in the second half of the 20th century, different immunological and hematological aspects of this organ were investigated. In 1968, the safety and success of non-operative management was demonstrated by Upadhyaya and Simpson.[6]

Having realized high ranking status of the spleen in provision of the immunity and also possibility of preserving a damaged spleen without operation, management of splenic injury, which was usually total splenectomy in most centers before 1970, changed gradually toward conservative treatment.[7] In fact, there have been many patients whom, upon exploration, were found to have stable clot on the lacerated spleen without further bleeding. Not only could the spleen, in this situation, be preserved in most patients with simple suturing, but also sometimes operation was terminated even without requiring any repair or further intervention.

The most dangerous complication after total splenectomy, or in those with asplenia, is overwhelming post-splenectomy infection occurring in 4.25% of the patients,[7] with a high mortality rate ranging from 45-70% in a short period of time.[2,7-16] Compared to normal population, patients undergone splenectomy as a result of trauma are estimated to have 58 times more chance to develop septicemia.[7,15] Death rate from over-whelming post-splenectomy infection has also been reported to be as high as 600 times greater than normal population.[14] Therefore, the importance of having an intact spleen cannot be overemphasized. Thus, every attempt after trauma to the spleen should be made to preserve the whole, or at least a part of the organ. For the same reason, several types of procedures have been performed in hypersplenic states to reduce the bulk of the splenic substance, while preserving, at least to some extent, the patient's immunity. These procedures include partial splenectomy: conventional,[17-19] or laparoscopic,[20-22] partial splenic embolization,[23,24] partial de-arterialization of the spleen,[25] and recently radio-frequency ablation.[26]

The main purpose of this review is to provide adequate knowledge, when facing a patient suspicious of internal bleeding probably secondary to splenic injury, to answer the following questions:
A) How should the situation be handled?
B) What are the mandatory paraclinical investigations?
C) How far should non-operative management be continued and when is operative intervention indicated?
D) What are the appropriate decisions and options during operation?
E) Is there any role for splenic auto-transplantation after total splenectomy?
F) What are the necessary measures or steps following non-operative management versus partial splenectomy or total splenectomy before or after hospital discharge? and
G) What are the functional (non-anatomical) related complications after total splenectomy other than over-whelming post-splenectomy infection?

A- How Should the Situation Be Handled?

General Considerations

Because of the combining effects of different variables such as soft tissue injury (or injuries) accompanied by blood loss, which is frequently associated with bone fracture, physiologic response after trauma is different from simple

non-traumatic hemorrhage (for example secondary to duodenal ulcer). To diminish the cascade of proinflammatory activation or cytokinemia, immediate control of bleeding, correction of hypotension or hypovolemia and tissue oxygenation by adequate volume replacement with an appropriate fluid, and proper management of each of the injured organs are mandatory steps. Worth mentioning, in young healthy individuals with good sympathetic tone, particularly children, hypotension does not occur unless 25-30% of blood volume is lost.[27,28] Thus, one should not be misled or misguided by an apparently within-normal range blood pressure in this group of patients. Regardless of its origin, internal bleeding has to be managed primarily conservatively for a while as there has been volume loss, which must be replaced initially with a bolus of isotonic crystalloid solutions (adults one liter normal saline or Ringer's lactate, and children 20cc/kg of the same solutions) to be repeated once more in the adults and twice more in the children if signs of hypotension or low tissue perfusion state are still present.[28]

Having administered adequate crystalloid fluids, the next fluids to be transfused depend upon the estimation of blood volume loss and presence or absence of signs of adequate tissue perfusion as determined by a combination of variables such as mental status, blood pressure (normally greater than 110 mmHg systolic in adults; above 80 mmHg in children), pulse pressure (normally not less than 20 mm Hg), pulse rate and its quality, peripheral perfusion assessed by capillary refill time (normally not longer than 2 seconds), urine output, and hematocrit or hemoglobin drop.[29] As a reliable measure and good index in monitoring the resuscitation phase of trauma care, base deficit resulting from tissue hypoperfusion with increased levels of lactate and carbonic acids reflects the degree of intravascular volume depletion and also adequacy of fluid therapy or blood transfusion.[30-34] It has been shown that there is a correlation between the extent of base deficit and degree of shock with the volume of fluid or blood required for resuscitation.[30,32-34] Not only severe (≥10 mmol/L deficit in new category),[34] but also moderate base deficit (6-9 mmol/L deficit) is indicative of severe injury and also subsequent significant morbidity and mortality.[33] The greater the base deficit, the higher the frequency of adult respiratory distress syndrome, multiple organ failure, and mortality.[30,32-34] High base deficit would also indicate abnormal oxygen utilization.[30,34] Furthermore, when base deficit

persists or increases in spite of resuscitation, ongoing bleeding should be suspected.[30] In a retrospective study, Davis and colleagues showed that 65% of such patients had had persistent bleeding.[31]

Hypertonic Fluid Therapy in Traumatic Hemorrhagic Shock and Its Modulatory Effects on Immune Factors

Owing to its effect on causing shift of the intracellular fluids towards the intravascular space, some authors have recommended hypertonic saline (7.5% NaCl) with or without dextran for the treatment of hemorrhagic shock.[35,36] However, acting as an arteriolar vasodilator with probable chance of increased bleeding, there have been concerns using hypertonic saline in a traumatized patient. For this reason and also its questionable efficacy, some clinicians are reluctant to use it in trauma. Wade and his associates in a meta-analysis of controlled prospective randomized clinical studies in patients with trauma showed that hypertonic saline did not improve survival as compared with those receiving isotonic saline.[37] Similarly, Vassar and colleagues in a multicenter trial have shown that there is no significant difference in overall survival between lactated Ringer's-treated group and those receiving hypertonic saline with or without dextran.[36] However, when compared with the survival as predicted by Major Trauma Outcome Study norms,[38] prehospital infusion of 250 ml 7.5% NaCl (with or without dextran) followed by conventional isotonic fluid therapy would be associated with rise in blood pressure and remarkable improvement in survival (P<0.001).[36] Nonetheless, hypertonic saline dextran may have more positive impact on survival and may be superior to normal saline.[37] According to Alpar and Killampalli, it has been confirmed that hypertonic saline dextran has a place in the treatment of hypovolemic shock in critically injured patients.[35] Furthermore, hypertonic saline has been shown to be mostly beneficial in those in shock state accompanied with head injury especially if associated with low Glasgow Coma Scale scores.[36,37]

More importantly, whether or not it is hemodynamically effective in trauma, hypertonic saline is a fluid to modulate immune function in these patients. In other words, it probably has some inhibitory or modulatory effects on proinflammatory (including cytokines) or immune factors.[39] It has been shown that hypertonic saline resuscitation limits neutrophil activation after traumatic hemorrhagic shock.[40] As a physiologic response after hemorrhagic

shock, mesenteric lymph production is decreased. Considering the process of neutrophil priming by post-shock mesenteric lymph, Zallen and co-workers have demonstrated that after induction of hemorrhagic shock in rats, mesenteric lymph volume was significantly higher in those receiving Ringer's lactate than hypertonic saline.[41] Thus, owing to low mesenteric lymph production following administration of hypertonic saline, neutrophil priming will be eliminated.[41] Therefore, chance of organ injury will be reduced. On the contrary, resuscitation with Ringer's lactate leads to neutrophils which would be primed for superoxide production leading to multiple organ injury (especially lung injury).[41]

Resuscitation of hemorrhagic shock by hypertonic saline has protective effect on lungs for the following reasons: 1) because of reduced gut ischemia/reperfusion injury, systemic oxidative stress is prevented. Consequently, alveolar macrophage priming would be attenuated,[42] and 2) it up-regulates the anti-inflammatory response by alveolar macrophages; i.e. tumor necrosis factor-alpha production is inhibited while release of interleukin-10 is enhanced and organ injury may be prevented.[43]

Other Necessary Steps

For obvious reasons, decompressing the stomach by an appropriate size nasogastric tube and the bladder by an internal Foley catheter should be part of resuscitation. Hypothermia in all ages, particularly children, should be avoided. Fortunately in most cases, even those who have been brought too late, the patient's general condition and vital signs, particularly after initial fluid therapy, are good enough to allow a quick survey such as ultrasonography or preferably focused abdominal sonography for trauma. And if necessary, abdominal computed tomography (CT) with double contrast (oral and intravenous) agents should be used. On the other hand, in minority with unstable vital signs, deteriorating general conditions, and unresponsiveness to medical therapy, urgent exploration may deem necessary.

B- What Are the Mandatory Paraclinical Investigations?

Diagnostic Peritoneal Lavage

Once used frequently after abdominal trauma, diagnostic peritoneal lavage is now less commonly performed as a diagnostic tool in solid organ injury.[28] The technique and criteria of positive lavage are not within the scope of this review article. Although diagnostic peritoneal lavage is relatively fast, accurate, and

highly sensitive to the presence of blood with rare possibility of false positive results,[44,45] it has low specificity.[46,47] False positive results may occur in the presence of pelvic fracture and retroperitoneal hematoma or may be resulted from the bleeding of the abdominal wall.[46] Significant injuries may also be missed. Furthermore, complications secondary to iatrogenic injuries may infrequently occur.[46,48] However, it is a valuable procedure particularly when sonography is not available or reliable and in hemodynamically unstable or hypotensive patients with neurological impairment who have unexplained etiology for blood loss without obvious indication for laparotomy. Encouraging results have also been obtained by using the dipstick in the evaluation of abdominal trauma.[49]

Focused Abdominal Sonography for Trauma:

Focused abdominal sonography for trauma as a replacement for diagnostic peritoneal lavage is not only sensitive, but also quicker and non-invasive.[8,48] Several investigators have obtained high sensitivity, specificity, accuracy, and negative predictive value by ultrasonography or focused abdominal sonography for trauma.[50-52] Therefore, when the result of the sonography is negative (normal) in a stable patient, because of its high negative predictive value, clinical follow-up is adequate and no further study would be required.[52,53] Branney and colleagues showed that when key clinical pathway is considered as base, sonography can safely be used in most (65%) of injured patients without requiring invasive diagnostic peritoneal lavage or costly CT.[53] In general, focused abdominal sonography for trauma is mostly indicated in unstable patients with multiple injuries because the procedure, in expert hands, does not take more than 3 minutes.[8] On the contrary, Kuncir and Velmahos believe that in hypotensive patients with hemodynamic instability secondary to intra-abdominal hemorrhage requiring emergent operation, diagnostic peritoneal aspiration (without a full lavage) is not only accurate, rapid, and safe but also superior to focused abdominal sonography for trauma.[45]

In a retrospective study by Farahmand and co-workers, in 128 hypotensive patients (blood pressure ≤90 mm Hg) with blunt abdominal trauma, accuracy of screening by sonography was evaluated.[54] Presence of free fluid and parenchymal heterogeneity in visceral organs were considered. Those with free fluid were scored according to the number of fluid pockets visualized by three radiologists. The results were then compared with findings in CT, clinical course, laparotomy, or autopsy. Sensitivity

was correlated to the degree of injury; the worse the injury, the higher the sensitivity. It was 85% for any injury, 97% for injuries requiring surgery, and 100% for fatal injuries.[54] In contrast, specificity was 96%, 82%, and 69% respectively. Accuracy was also 91%, 86%, and 71% for the previous respective categories.[54] Those with fluid score of 2 or more had nine times more chance of frequency of injury compared with those with zero score. On the other hand, false-negative sonography in high risk patients was eight times more than low risk patients. These authors concluded that hypotensive patients after abdominal trauma who were not hemodynamically stable to undergo CT, should be screened by sonography.[54] If the result of sonsography is negative, surgical injury is virtually excluded, while when it is positive about two third of these patients have an injury that may need operation.

Lack of intra-peritoneal fluid is not against solid organ injury.[55] Although, sonography is highly accurate, specific, and relatively sensitive,[48,51,52,56] combination of free fluid and parenchymal abnormality increase the accuracy and sensitivity of this procedure for detection of solid organ injury as well as free fluid.[51] Similarly, in some case series, sonography has been relatively sensitive for detection of free fluid or solid organ injury in the presence of free fluid, while its value for diagnosing organ injury not associated with free fluid is limited.[57] Because of its non-dependent position, more free fluid (mean volume 619 ml) is required to be detectable in sonography of the Morison's pouch as compared with pelvic cavity.[58] When less than 400 ml fluid is present in the region, detection of any volume is unusual, while the overall sensitivity at one liter would be 97%.[59] Thus, to increase the accuracy and reliability of the procedure, sonography may be performed in Trendelenburg position to have more accumulation of fluid in Morison's pouch.[60] Despite several achievements, anatomic delineation by sonography is not accurate especially in the presence of abdominal distension, obesity, or pregnancy. However, owing to its low cost and other advantages such as lack of radiation, focused abdominal sonography for trauma is recommended for screening as an alternative to more costly CT.

A New Modality of Ultrasonography

Contrast-enhanced ultrasonography is a new procedure with encouraging preliminary reports. In this procedure, the contrast medium (Sono Vue) is stabilized aqueous suspension of sulfur hexafluoride microbubbles with a phospholipid shell. These microbubbles are small enough to pass the sinusoidal system in the lung, liver, and spleen. Owing to low solubility of the gas of Sono Vue and high resistance of its shell to the mechanical effect of sonography beam, the agent will have a long sustainability. For this reason, all vascular phases (arterial, parenchymal, and venous) can be evaluated. These microbubbles produce a high amplitude signal which is acquired by a special transducer. For visualization of the left upper quadrant organs (spleen, kidney, adrenal gland), 2.4 ml Sono Vue is injected. A few minutes later, the same dose is repeated for examination of the right upper quadrant organs (liver, pancreas, kidney, adrenal gland).

Valentino and others performed contrast-enhanced CT, sonography, and contrast-enhanced sonography in 27 children (19 boys, 8 girls) with blunt abdominal trauma.[61] In 15 patients contrast-enhanced CT findings were normal, while the remaining 12 patients had 14 solid organ injuries. Comparatively, contrast-enhanced sonography could depict 13 of the 14 lesions already detected by CT with no lesions in those 15 patients whose CT were also negative.[61] On the contrary, un-enhanced sonography detected free fluid in 2 of 15 patients with normal CT, while free fluid, parenchymal lesions or both could be observed in only 8 of 12 patients with positive CT findings.[61] These authors concluded that diagnostic performance obtained by contrast-enhanced sonography with very high sensitivity, specificity, accuracy, positive and negative predictive value was not only superior to those of un-enhanced sonography, but also almost as accurate as contrast-enhanced CT in detecting solid organ injury in children.[61]

The New Generation of CT and Its Advantages

The current generation of CT scanners (helical and spiral) is rapid with high resolution. Compared with previous technology requiring 15-20 minutes, the new generation takes only 1-2 minutes to complete the examination. Furthermore, quality and precise delineation of the injured organ along with its vascular disruption is much superior to the previous version. Contrast-enhanced CT in stable patients improves the success rate of non-surgical treatment and helps for better decision. The newest generation of CT scanners is multislices. Multidetector CT, as a second line initial assessment tool in blunt abdominal trauma, is not only useful to identify injuries but also plays a major role in making proper decisions and treatment planning. Furthermore, sensitivity, specificity, and

accuracy of the procedure in patients with active bleeding and bowel, mesenteric or pancreatic injury is 100%.[62] Taking, on average, 10 minutes, when the facility is readily available, the protocol is well designed and the patient is well resuscitated and prepared, therefore, the patient would not be subjected to increased risk.[62]

C- How Far Should Non-operative Management Be Continued and When Is the Operative Intervention Indicated?

General Information

The mortality rate of non-operative management before the 20th century was more than 90%.[2,63] Currently, non-operative management is attempted in about two thirds (60-80%) of all patients with splenic injury, 85-94% of whom respond well without requiring any surgical interventions.[63] In a case series by Pachter and colleagues, about 90% of children and over 60% of adults with blunt splenic injury have been managed successfully without operation.[64] Nowadays, in referral trauma centers, 70-90% of children and 40-50% of adults with splenic injury are managed without operation.[8]

In spite of this remarkable response and high success rate, conservative therapy should be only continued when the following conditions are met: 1- relatively stable or acceptable vital signs (particularly blood pressure and pulse rate) after initial resuscitation; 2- admission in the intensive care unit (ICU) for high grade of splenic injury (grades IV-V and frequently grade III) or admission in the surgical ward with close monitoring for lower grades (I-II) or even somtimes in selected patients with grade III splenic injury; 3- lack of major concomitant intra- or extra-abdominal organ injury; 4- adequate cross-matched blood available; and 5- a stand-by medical team.

Based on the prospective results of a standardized algorithm, hemodynamically stable patients can even be managed without ICU monitoring.[65] In the absence of instability for any episode after trauma, others have also questioned the necessity of admision in the ICU.[66] When hemodynamically stable, others have proposed one day ICU admission for grade IV splenic injury and none for grades I-III.[67,68]

Owing to healthy and more responsive blood vessels to sympathetic over-activity in children, non-operative management is usually more successful in this group of patients compared with adults.[8,27,28] Another reason for this difference is decrease in "splenic capsule-to-parenchymal ratio" as the age increases, resulting in relatively

diminished tamponade effect inserted by the splenic capsule.[2] In addition, presence of more elastin in children's spleen compared with adults may contribute to more contraction of this organ and, to some extent, more effective hemostasis.[8] Moreover, because of less elasticity of the ribs in adults, disruptive splenic injury secondary to rib fractures occur more frequently in this group. In other words, adults are usually more severely injured.[69] Thus, the chance of conservative treatment failure is higher in adults compared with children.

Having evaluated retrospectively the short-term outcomes of different types of management strategies performed in 170 adult patients with splenic injury (blunt and penetrating), Kaseje and associates concluded that morbidity after splenic preservation i.e., observation, embolization, splenorrhaphy, or splenic salvage is 2- to 3-folds higher than morbidity after immediate total splenectomy.[70] In other words, in hemodynamically stable patients with splenic injury requiring some sort of intervention, total splenectomy, at least in short-term, may be associated with lower complication rate and morbidity compared with conservative (operative or non-operative) modalities.

Risk Factors; Who Should or Should Not Be Treated Conservatively

There is no age limit for non-operative management. Splenic injury has been managed medically in a very low birth weight (800 g) premature newborn.[71] On the other hand, rupture of the spleen has also been conservatively managed in adults 55 years or older with acceptable results.[72-74] In some case series, the failure rate of non-operative management in 55-year-old patients or older, in spite of sustaining greater injuries, has not been different from younger individuals indicating that age is not a contraindication for non-operative management,[72-74] provided the patient is stable, not suffering from associated injuries and without significant requirement to blood transfusion. Nonetheless, among patients older than 55 years, when age group of 55-64 years is compared with 65-74 years and those beyond 75, trend of failure rate of non-operative management is upward and correlated with increasing age.[74] However, this trend is not significant. In contrast, age over 55 years has been considered as risk factor and powerful indicator for failure by some other investigators.[75-77]

In a retrospective study performed by McIntyre and his associates on 2243 patients, risk factors for the failure of non-operative management were evaluated by regression analysis.[76]

Six hundred and ten (17%) patients required splenectomy, splenorrhaphy, or embolization within 4 hours. The remaining 1633 patients underwent conservative therapy, 252 (15%) of whom had failure. Age over 55 years, injury severity score higher than 25 and admission in level III or IV trauma hospital were found to be associated with remarkable chance of failure.[76] On the other hand, initial hemodynamics at the time of presentation, Glasgow Coma Scale (GCS) and associated injuries were not predictive of non-operative management failure.[76] In contrast, published contraindications for non-operative management reviewed by Bee and colleagues, were not only 55 years of age or older and GCS≤13, but also an initial blood pressure less than 100 mmHg and high grade splenic injury associated with large volume hemoperitoneum.[75] These authors reviewed 558 patients with splenic injury during a 46-month period, 430 (77%) of whom were observed.[75] Failure of non-operative management occurred in 8%. The independent factors predictive of failure as identified by multivariable analysis included age ≥55 years and also grade III-V splenic injury especially when associated with moderate to large hemoperitoneum. Nevertheless, according to these authors, none of the factors alone are necessarily contraindication for non-operative management.[75]

According to Potoka and co-workers, risk factors influencing the final results in children with increasing chance of operation include severity of splenic injury, presence of extra-splenic intra-abdominal organ injury, GCS 3-8 and age of the patient (15-16 years old).[78] In the case series by Stylianos and co-workers, independent risk factors for total splenectomy included the severity of the spleen injury (P<0.0001), age of the patients (15-19 years, P<0.002), and presence of multiple injuries (P<0.04).[79] Furthermore, risk of splenic operation was significantly higher in patients being treated at a non-trauma center (P<0.0001).[79] Similar results have been obtained in another case series reported by Davis and co-workers in which 3245 children younger than 19 years with blunt splenic injury were evaluated during 1991-2000.[80] In this report, 752 (23.2%) patients were managed operatively. Probabilities of total splenectomy as determined by multi-variable logistic regression models were related to age and severity of the splenic injury; the higher the two latter variables, the more the chance of operative management.[80]

The Factors Influencing Success Rate of Non-operative Management
There is a correlation between grading of splenic laceration and probability of non-operative management success rate. As the grading of splenic injury increases, the overall salvage rate of the spleen declines.[81] For example, in-hospital success rate for mild splenic injury (grade I-II) approaches 95%, while this figure for severe types (grade III-V) is about 82%.[63] In study by Davis and colleagues, non-operative management of higher grades of splenic injury (IV and V) has been associated with 18% failure rate.[82] Quite similarly, non-operative management of grades IV and V splenic injury by Haan and associates has also ended-up with about 20% failure rate.[81] According to the data collected from 832 children sustaining grades I-IV isolated splenic injury or liver injury (grade V excluded) treated at 32 pediatric surgical centers (July 1995-June 1997), 12.6% of the patients with grade IV injury required surgical intervention while only 2.7% of those with grade III injury underwent operation (P<0.0001).[67] It has also been shown that there is a correlation between large volume intra-peritoneal free blood in CT and failure rate of non-operative management.[72,75,82] On the contrary, in other seris, extent of splenic injury and quantity of hemoperitoneum have not been consistently predictive of non-operative management failure.[81,83]

In children, conservative treatment of splenic injury performed by pediatric surgeon, rather than being managed by the adult surgeon, has been associated with more fruitful results.[84,85] Similarly, satisfactory outcome has been obtained in patients of all ages by trauma surgeons.[86] As experiences in the management of abdominal solid organ injury improves, the frequency of non-operative management particularly in trauma centers rises.[87] In Rutledge and co-workers study, during the 5 years of study (1988-1992), the rate of successful non-operative management of splenic injury increased from 35% to 44% in non-trauma centers compared with 33% changing to 49% in trauma centers (P<0.05).[88] Rate of successful non-operative management for both multiply injured patients and those suffering from isolated splenic injury has also been significantly higher in other series in trauma centers compared with non-trauma centers.[78,79]

Timing, Values, and Risks of Blood Transfusion; Is It Worthwhile?
To maintain the patients stable, Cosentino and colleagues, have managed successfully splenic and hepatic injury without operation in childhood while requiring 16-21 cc packed cell/kg/day to correct hemoglobin drop when Hb

was less than 8 gr% (Hct 24-25%).[89] Siplovich and Kawar have managed 18 children under 14 years of age with isolated splenic injury without blood transfusion unless Hb drops below 7 gr% (Hct<20%).[90] Only one patient underwent operation (splenorrhaphy) for hemodynamic instability. In the study performed by Stylianos and American Pediatric Surgical Association on 832 children with isolated splenic injury or liver injury, transfusion rate in those with grades I through III injuries was 2-10% and for grade IV was 26.6% (P<0.014).[67]

Owing to more frequent blood transfusion in some patients with non-operative management compared with those treated operatively, risks of blood transfusion-related diseases or mortality may be higher in the former group. It has been shown that in those who undergo non-operative management, blood transfusion in the first 24 hours after trauma as an independent factor (after control of shock index and injury severity index), increases chance of mortality to three folds.[91,92] This is particularly true when allogenic blood is transfused, which may be related to increased chance of systemic inflammatory response syndrome.[93] Nevertheless, because of the chance of overwhelming post-splenectomy infection and its mortality, risks of blood transfusion outweigh benefits of total splenectomy. In a study performed by Velanovich and Tapper, quality-adjusted life expectancy (QALE) was used to analyze and compare different treatment options (non-operative management *vs* splenorrhaphy *vs* total splenectomy).[94] Although transfusion rate was sometimes higher in patients who needed splenorrhaphy, when non-operative management was compared with splenorrhaphy, QALE was similar in children. However, those with non-operative management and splenorrhaphy had longer QALE than total splenectomy. Interestingly, they found out that even if 100% of the observed individuals and none of the total splenectomy patients had blood transfusion, QALE was still shorter for total splenectomy.[94] In other words, operatively or non-operatively, life expectancy is increased by splenic preservation.

Timing of Operation versus Observation and Hospital Discharge

Failure of non-operative management, especially if associated with multiple or severe injuries, usually occur within 12 hours of management.[67,95,96] In a retrospective analysis performed by Holmes and associates on 1818 patients (aged 0-20 years) sustaining solid organ injury (liver, spleen, kidney, or pancreas), failure of non-operative management in 76% of patients occurred within the first 12 hours after injury.[96] Moreover, the failure rate was correlated not only with injury severity but multiplicity of traumatized organs especially in the presence of pancreatic injuries.[96] In Nance and colleagues' study, 80% of those requiring surgery did so within 6 hours after trauma, while in the following 18 hours (24 hours after accident), only 10% was added to that figure.[97] In other words, 90% of patients requiring exploration underwent laparotomy during the first 24 hours after trauma.[97] Thus, the first 24 hours (especially first 12 hours) is the most critical and determining time in the management of splenic laceration. To formulate the timing of hospital discharge, duration of hospital stay (or actually strict bed rest) in days, in a hemodynamically stable patient is equal to grade of splenic injury plus one.[67,68] Recently, following a retrospective analysis of 243 children (mean age 9±4.6 years), an abbreviated protocol in the management of splenic injury and liver injury in children has been suggested by St Peter and co-workers.[95] Having been hemodynamically stable with no signs of ongoing blood loss, for grades I and II splenic injury one night and for higher grades two nights observation is safe and would suffice.[95]

Although certain authors believe that operation is indicated when blood transfusion is considered mandatory,[98] others have recommended exploration when more than four units of blood is necessary to correct hypotension or hemoglobin drop.[2] The incidence of associated extrasplenic intra-abdominal injuries varies in different series ranging from 5% to 47% (average 15%) in those treated without surgical intervention.[2] On the other hand, owing to severity of injury, its incidence is higher (range 17-70%; average 55%) in those requiring total splenectomy or splenic repair including partial splenectomy.[2] In other words, mechanism of injury is usually, but not always, less severe in those responding to non-operative management, thus sustaining or giving rise to fewer intra-abdominal injuries. Although, associated organ injury has been accepted as exclusion criteria for non-operative management, its presence not requiring operation still justifies conservative treatment in a stable patient, provided other conditions for such a decision, as mentioned previously, are met.

Most patients, particularly adults, in the presence of contrast blush or arterio-venous fistula are more likely to undergo surgical intervention or embolization.[81,99-102] On the other hand, blush sign in children may be treated conservatively (even with higher grades of

injury), provided there is no hemodynamic instability.[100,103] In the study by Haan and colleagues, significant hemoperitoneum, and even extravasation, have been associated with acceptable non-operative management success rate, while presence of arterio-venous fistula has been predictive of 40% failure rate of non-operative management.[81,83] Unlike this study, others have shown that contrast blush or contrast extravasation in CT should be considered as an alarming sign because, similar to arterio-venous fistula, they are indicative of active hemorrhage.[99-102] Therfore, success rate of non-operative management would be reduced in the presence of these lesions. However, presence of each of those signs alone (contrast blush or arterio-venous fistula) is not determinant without considering vital signs and general condition of the patient, as in the absence of hemodynamic instability, these findings may be insufficient to subject the patients (especially pediatrics) to operation.

It should be noted that contrast blush is a regular well circumscribed lesion within the parenchyma often due to pseudoaneurysm of the splenic artery or its branches.[82,101] Although these lesions may not be visualized on initial CT scan, they may be detectable 48-72 h later and are sometimes the source of delayed bleeding.[82] Thus, depending on the patients' clinical course, to improve the non-operative management success rate, arterial embolization may deem necessary.[82] On the other hand, contrast extravasation that is usually seen at the first CT is defined as a collection of contrast material (because of the leakage out of the vascular system) with irregular border outside the splenic parenchyma.[104] Owing to often rapidly bleeding nature of these lesions, prompt hemorrhage control by surgical intervention or angiographic embolization should be anticipated.[83,98] However, intrasplenic hyper-attenuating foci on portal venous phase (sustained or increased in size) and delayed phase of CT differentiate patients with active bleeding from those with contained vascular injury such as pseudo-aneurysm or arterio-venous fistula.[105] The former group showing signs of active hemorrhage requires emergent operation (usually total splenectomy), while the latter group may be initially treated non-operatively.[105]

Role of Arterial Splenic Embolization

Partial arterial splenic embolization is occasionally performed in some centers as part of the non-operative management in splenic injury especially when it is severe,[106,107] or in selected stable patients particularly in the presence of contrast blush, arterio-venous fistula, or pseudo-aneurysm.[81,82,108] Major complications such as total splenic infarction, atrophy, post-procedure bleeding, abscess or contrast-induced renal insufficiency may occur in 27-28.5% of the patients.[109,110] Moreover, more than 50% of the patients (up to nearly two third) may develop minor complications including fever, pleural effusion, or partial splenic infarction.[109,110] Nevertheless, considering the unfavorable nature of these lesions for non-operative management, the importance of their identification and on-time treatment by embolization contributing to higher success rate cannot be overemphasized. In a report by Willmann and colleagues, 22 (13%) of 165 patients with blunt abdominal trauma undergoing multidetector CT had active hemorrhage (jet of extravasation of the contrast agent), 16 of whom had to undergo immediate surgical or angiographic intervention.[101] The latter procedure was performed in one patient 10 hours later. The remaining five patients died between 1 to 3 hours following CT. The authors concluded that active hemorrhage in patients after blunt abdominal trauma was most frequently visible as a jet of extravasated contrast agent on multidetector CT.[101] After detection, immediate surgical or angiographic treatment is required.

Gaarder and associates showed that the results of non-operative management improved when angiographic embolization was added to the protocol in patients with severe splenic injury (grade 3 to 5) or those with signs of ongoing bleeding regardless of splenic injury grade.[107] In this study, the success rates of non-operative management in two matched groups before (group 1) and after (group 2) introducing angiographic embolization were compared.[107] Group 1 and 2 consisted of 69 and 64 patients with a mean Injury Severity Score of 31 and 30, respectively. In group 1, 30 of 69 (43%) patients had to undergo immediate laparotomy, while 17 of 64 (27%) patients in group 2 were subjected to surgical intervention (P<0.04). The success rate of 79% for non-operative management in group 1 increased to 96% in group 2 (P<0.02). Furthermore, the overall splenic salvage rate increased from 57% to 75% (P<0.02).[107] Compared to conventional non-operative management, high rate of success of non-operative management has also been achieved with selective splenic embolization by Dent and associates (65% v 82%; P<0.01).[111] The latter procedure in a report by Davis and colleaguse caused significant improvement in the reduction of failure rate

of non-operative management (6%; P<0.03) compared with their previous work.[82] Furthermore, remarkable splenic salvage rate would be obtained when pseudoaneurysm of the splenic artery is detected by serial CT and subsequently managed by angiographic embolization.[112]

Although higher grades of splenic injury are more likely associated with pseudoaneurysm of the splenic artery compared with mild splenic injury, in the report by Weinberg and co-workers, nearly a quarter (24%) of pseudo-aneurysms of splenic arteries were detected in the latter group.[112] Therefore, regardless of the severity of splenic injury, serial CT surveillance is advised in patients sustaining this type of injury, in order not to miss the pseudoaneu-rysms of the splenic artery. In general, in spite of possibility of continuous bleeding or occur-rence of re-bleeding in the presence of already mentioned vascular lesions, or technical failure precluding embolization, this valuable proce-dure (angiographic therapy) in stable patients, if possible, is worth to try as it may obviate an operation and, more importantly, could save the spleen.[81-83,107-112]

Delayed Rupture of the Spleen after Injury and Its Management

Delayed rupture of the spleen (48 hours or more [up to one month] after injury; mostly dur-ing 2 weeks after injury) occurs in 10-15% of cases.[2] The underlying pathophysiology of this phenomenon is mostly related to pseudoaneu-rysm of the splenic artery branches inside the parenchyma.[8,113] Not all pseudoaneurysms of the splenic artery rupture, as about 30-40% of which undergo thrombosis.[102] Other causes of this complication include: 1- hyperosmolar envi-ronment in the presence of hematoma and bro-ken-down hemoglobin causing water absorp-tion, increase in its dimension and pressure with eventual rupture,[114] 2- subcapsular hema-toma,[113,115] or 3- pseudocyst of the spleen.[113] Farhat and colleagues believe that subcapsular hematoma is the most common cause of this problem.[115] According to them, lesser trauma following minor fights or falls more likely lead to this complication, while more severe injury usually causes immediate (not delayed) splenic rupture.[115] In the study by Parithivel and co-workers, there were eight patients pre-senting 2-10 days after blunt splenic injury all of whom had an underlying medical condition such as drug addiction, cirrhosis, sickle cell disease, or were HIV positive.[116] One patient presented in shock requiring emergency lapa-rotomy after positive diagnostic peritoneal lav-age, four patients developed acute abdomen,

and three had abdominal pain with anemia.[116] Abdominal CT revealed hemoperitoneum in the seven stable patients. Nevertheless, sple-nectomy had to be performed in all.[116] In an-other study, potentially life-threatening delayed complications requiring surgical intervention was reported by Cocanour and colleagues in seven (8%) of 87 patients treated non-operatively: five patients had re-bleeding at days 4, 6, and 8 after splenic injury; two other patients developed splenic abscess in about 1 month after the injury.[117]

Regardless of the underlying etiology, re-sponse to non-operative management follow-ing delayed splenic rupture is unusual as there is low chance of hemostasis. For this reason, surgical intervention should be performed promptly if morbidity and mortality are to be reduced and prevented. Therefore, while still in hospital, the patients undergoing non-operative management and their close relatives must be informed of these complications and their signs and symptoms. Should the patient develop related problems after discharge (signs of acute blood loss or acute abdomen usually associated with Kehr's sign, fever, etc.), imme-diate referral to the hospital for further man-agement would be life-saving. In long-term, however, less than 0.5% of the patients being treated by non-operative management may develop late complications or sequelea such as splenic cyst or abscess.[118] Management of the lesions, depending on the patient's condi-tion, includes percutaneous or open drainage, excision of the cyst (with partial splenectomy) or total splenectomy.

Rupture of the Spleen in the Presence of Pathological Conditions and Its Management

Although rupture of the pathological spleen usually requires surgical intervention, successful non-operative management has been reported in some of these pathological states.[88] Guth and co-workers successfully treated 11 male adult patients, eight of whom had trauma to the spleen (grade I to IV) with HIV-associated splenomegaly while the remaining three had spontaneous splenic rupture resulted from in-fectious mononucleosis, acute leukemia, and sickle cell anemia.[88] In addition, splenic injury has also been treated successfully in hemophilic pa-tients without requiring operation.[119,120] There-fore, non-operative therapy has a place in man-aging some of these patients with a good re-sponse to resuscitation and stable vital signs without deterioration of the clinical conditions. On the contrary, splenic injury in cirrhotic patients owing to portal hypertension, splenomegaly, and

impaired coagulation system, has un-favorable outcome if managed medically.[121]

Role of Laparoscopy in Abdominal Trauma

In hemodynamically stable patients with equivocal abdominal signs, several authors have used laparoscopy as a valuable adjunct in the evaluation of both penetrating and blunt abdominal trauma.[122-126] This procedure is not only diagnostic but can also be therapeutic. Kaban and others, performed diagnostic laparoscopy over a 4-year period in 25 and 18 patients after penetrating and blunt abdominal trauma, respectively.[122] Determinant and useful results were obtained in both groups. In the blunt trauma group, 12 patients had positive findings nine of whom had to be explored (50% of 18), while the remaining six (33%) had negative findings in laparoscopy. The reported sensitivity and specificity of the procedure in this series in blunt abdominal trauma was 92% and 100%, respectively.[122]

Chol and Lim used laparoscope in 78 hemo-dynamically stable patients following abdominal injury (52 blunt traumas, 26 stab wounds) and significant CT findings.[123] Laparoscopy in 13 patients was diagnostic, while in the remaining 65 (83%) patients was therapeutic, including two total splenectomy. A variety of other procedures were successfully performed in this series (gastric wall repair, colon repair, Hartmann's procedure, small bowel resection-anastomosis, distal pancreatectomy, control of bleeding from the omentum or bowel mesentery, cholecystectomy).[123] Olmi and colleagues, have used fibrin glue as a hemostatic agent laparoscopically as an effective alternative in the management of splenic injury.[126] Absorbable mesh splenor-rhaphy has also been performed via laparo-scopy for grade III splenic injury.[127] Other advantages of this procedure are as follows: a) blood salvage and auto-transfusion,[125] b) avoiding negative or unnecessary laparotomy, and c) reduction of total hospital cost.[124]

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