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**SUMMARY**

The liver is the most commonly injured organ within the abdomen. Dr Fabian and his associates have made remarkable contributions to our understanding and management of these injuries. The current review summarizes the contributions.

**REVIEW**

While small lacerations of the liver substance may be, and no doubt are, recovered from without operative interference: if the laceration be extensive and vessels of any magnitude are torn, hemorrhage will, owing to the structural arrangement of the liver, go on continuously.

James Hogarth Pringle, 1908<sup>1</sup>

The liver is the most commonly injured organ within the abdomen. Historically, major injuries of the liver have had an extremely high mortality related to hemorrhage, infectious complications, and the association of major liver injuries with other intra-abdominal injuries. In the early part of the 20th century, liver injuries were associated with mortality approaching 70%, with the majority of patients dying from uncontrollable hemorrhage. In 1908, James Hogarth Pringle, an Australian-born British surgeon, described compression of the hepatoduodenal ligament—Pringle maneuver—to temporarily control bleeding, allowing the surgeon to identify and suture ligate bleeding vessels. He described the principles of operative management of liver injury as (1) controlling bleeding with compression of the hepatoduodenal ligament, (2) suturing of the bleeding surface and (3) packing for bleeding not controlled by suturing.<sup>1</sup> These principles continued to be followed until the middle of the 20th century including World War I and the inter-World War period. Mortality remained stubbornly high at ~60%.<sup>2-3</sup> From the beginning of the century, multiple surgeons had noticed that bleeding from liver injuries, especially minor ones, had often stopped spontaneously by the time of surgery.<sup>4-6</sup> Despite this observation, the general consensus was that operative control was the correct approach, and in 1942, the Committee on Surgery of the National Research Council recommended that in the war theater, operative management was to be pursued.<sup>7</sup> With improved resuscitation, including the use of blood, earlier evacuation from the field and refinements in operative techniques, mortality fell to ~30% during World War II.<sup>2</sup> There was a strong feeling among surgeons managing liver injuries during World War II that gauze packing, as advocated by Pringle, was associated with numerous complications and high mortality. Hence, packing was abandoned, and a strong preference for wide drainage emerged.<sup>8</sup>

Post-World War II, the principles of management were (1) Pringle maneuver; (2) suturing of bleeding surface, preferably using 'blunt' needles; and (3) wide drainage often using multiple drains.<sup>9-10</sup> These guiding principles were followed for the next two decades. In the 1960s and early 1970s, selective hepatic artery ligation and T-tube drainage of the common bile duct were espoused but quickly fell out of favor.<sup>10-13</sup>

One of the major issues surrounding operative management of liver injuries is how to deal with the raw parenchymal surface that can be a source of major hemorrhage and bile leak. Any form of suturing is technically frustrating, and the closed off cavity invariably accumulates a mixture of blood and bile and has a high incidence of infective complications, recurrent bleeding and hemobilia. A novel technique—omental packing—was described by Stone and Lamb that consisted of packing viable omentum into the cavity. The initial report was of 35 consecutive patients where the technique had been used.<sup>14</sup> The technique was refined, and a larger series of 113 consecutive patients with major liver injury was published by Fabian and Stone in 1980.<sup>15</sup> In their report, mortality was 8% with an acceptable relatively low rate of complications. Omental packing remains a viable technique for management of large open liver injuries. The technique was evaluated prospectively as part of a landmark prospective randomized trial of 482 consecutive patients with liver injury by Fabian *et al*, that compared drains versus no drains and within the drainage group, open drains versus closed suction drains. The study was and remains one of the largest prospective studies to be performed on patients with liver injuries managed operatively with an overall mortality of 5.6%. The study demonstrated that patients with liver injuries (1) could be managed without drains, challenging one of the long-standing tenets of management; and (2) if drains were to be used, closed suction drains were superior to open drains. Additionally, omental packing was used in 60% of the 144 major injuries with a mortality of 7% and an infectious complication rate of 8%, much superior to what had been reported in the past. Finally, the study also resurrected the use of gauze packing in patients who were coagulopathic. It was used in 10% of patients with major liver injuries and was associated with mortality of 29% and infectious morbidity of 30%—remarkable results for patients in extremis and at imminent risk of dying.<sup>16</sup>

In the 1980s, the American Association for the Surgery of Trauma developed and published organ injury scales (OIS) for all part of the body. These scales were developed to provide a uniform language for severity of injury, both in clinical practice and for research. With the advent of CT, OIS

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grade could potentially be deduced from imaging. One of the earliest studies evaluating this possibility for liver injuries was performed by Croce *et al* and published in 1991.<sup>17</sup> Through careful analysis and comparison of injury grade as determined by preoperative CT scan and at surgery, they were able to provide an objective comparison and the pros and cons of each approach. With improvements in CT technology, the accuracy of CT grading has improved tremendously, but the study remains relevant as it offers a methodology of how OIS should be evaluated through the lens of different modalities. That methodology has been, and continues to be, emulated for other organ injuries and, more recently, for non-traumatic emergency general surgery conditions.

A paradigm shift in management of liver injuries from near universal surgery to non-operative management occurred in the late 1980s and accelerated in the 1990s. This was the result of the widespread availability of CT scanning that quickly supplanted diagnostic peritoneal lavage as the preferred method of evaluating the abdomen after trauma in hemodynamically stable patients. Patients with liver injury who are hemodynamically stable constitute the majority of patients with liver injury. In such patients, the liver injury has almost always stopped bleeding, and hence the injury can potentially be managed without surgery. CT scanning allows for accurately diagnosing and grading the liver injury, and more importantly, reliably excluding other intra-abdominal injuries that may need surgery.<sup>18</sup> Starting in the mid-1980s, a number of reports of successful non-operative management of hemodynamically stable patients with liver injury were published. All but one of these reports were retrospective, reporting on a small number of patients, the majority of whom had low-grade injuries.<sup>19–28</sup> The sole exception was an attempt at a randomized study, but the groups, despite randomization, were not well matched.<sup>29</sup> The first true prospective study that addressed the question of managing *all* hemodynamically stable patients with liver injury non-operatively was performed by Croce *et al* and published in 1995.<sup>30</sup> The study evaluated 136 consecutive patients with liver injuries. Unstable patients underwent immediate laparotomy (n=24), and stable patients underwent CT scan. Patients who remained stable and did not have any other indication for laparotomy were managed non-operatively, irrespective of grade of liver injury (n=112). Twelve of the non-operatively managed patients failed non-operative management, of which five failures were liver related.

The 100 patients who were successfully managed without surgery were compared with a matched historical cohort of operatively managed patients. Not only did these 100 patients avoid surgery, but also their transfusion requirements and rates of complications were significantly lower. This initial pilot study was followed by a much larger study of 661 patients where the sole criterion for non-operative management was hemodynamic stability irrespective of liver injury grade published by Malhotra *et al* in 2000.<sup>31</sup> In this much larger study, the 661 patients were compared with two previous groups: operatively managed (n=168) and the pilot non-operative (n=136). This study was unique in that it did not compare the operated patients to ‘matched’ patients managed without surgery; rather, the study compared two strategies: operative, where all patients are managed operatively, versus non-operative, where only patients with surgical indications—hemodynamic instability, other injuries requiring surgery, and failure of non-operative management—were managed with surgery. When the entire cohorts were compared, transfusion requirements, infective complications and hospital length of stay were significantly lower in the two non-operative cohorts as compared with the operative cohort, despite surgery being used in the two non-operative cohorts only about 20% of time. Interestingly, liver-related mortality across the three cohorts was nearly identical at 4%. The study also asked the question whether the patients initially managed non-operatively and then underwent surgery for failure of non-operative management were harmed by the delay in surgery? While it is almost impossible to be absolutely certain, the study used innovative comparisons to demonstrate, as best as can be, that the delay in surgery was not harmful to the patients who failed non-operative management. The study was presented at the 111th Annual Meeting of the Southern Surgical Association, where, commenting on the study, Dr LD Britt remarked, ‘While this is not the first nail in the coffin of operative management of solid organ injuries, I do believe that the medical historians will ultimately assess this as being the biggest nail’. (In another first, this was the first time that a PowerPoint presentation from a computer, as opposed to physical slides, had been utilized at this very traditional society. While the society allowed Dr. Fabian to present using PowerPoint, it could not guarantee a computer compatible projector. Not to be dissuaded, Dr. Fabian lugged a very heavy and bulky (as these projectors were in 1999) computer compatible projector, as his carry-on luggage and presented using a computer and the self-brought projector.) These

**Table 1** List of publications by Dr Fabian and associates in the field of liver injury

Authors	Methodology	Principal conclusions/findings
Fabian and Stone <sup>15</sup>	Retrospective analysis: omental packing	Effective method with low morbidity and mortality
Fabian <i>et al</i> <sup>16</sup>	Prospective randomized trial and analysis: 482 consecutive liver injuries	<ol style="list-style-type: none"> <li>1. Drainage not essential.</li> <li>2. Closed drains superior to open drains.</li> <li>3. Omental packing is a highly effective technique.</li> <li>4. Gauze packing is lifesaving in coagulopathic patients.</li> </ol>
Mangiante <i>et al</i> <sup>32</sup>	Retrospective description: intraparenchymal haemobilia after trauma	Description of etiology, diagnosis and management
Croce <i>et al</i> <sup>33</sup>	Case series: extraparenchymal hemobilia after trauma	Description of etiology, diagnosis and management
Croce <i>et al</i> <sup>17</sup>	Retrospective analysis: CT and operative AAST grading of liver injuries	<ol style="list-style-type: none"> <li>1. Comparative accuracy of CT versus operative grading.</li> <li>2. Methodology for comparative grading.</li> </ol>
Patton <i>et al</i> <sup>34</sup>	Case report	Trends in non-operative management of liver injuries
Croce <i>et al</i> <sup>30</sup>	Prospective trial: non-operative management of stable patients with liver injury	Non-operative management is superior to operative in stable liver injury patients
Malhotra <i>et al</i> <sup>31</sup>	Retrospective analysis: comparing operative vs non-operative strategy	<ol style="list-style-type: none"> <li>1. Non-operative strategy improves outcomes but not liver-related mortality.</li> <li>2. Delay in operative therapy of patients who fail non-operative management does not adversely affect outcomes.</li> </ol>
Malhotra <i>et al</i> <sup>35</sup>	Retrospective analysis: impact of multiplicity of solid organ injury	Multiplicity of solid organ injury increases rates of operative management: initial and after failure
Cox <i>et al</i> <sup>36</sup>	Retrospective analysis: usefulness of follow-up imaging after liver injury	Follow-up imaging is unnecessary after blunt liver injury.

AAST, American Association for the Surgery of Trauma.

two major studies of non-operative management of liver injury have together been cited over 1200 times.

In summary, Dr Fabian and associates have contributed greatly to our understanding and management of liver injuries (table 1). Through groundbreaking studies of high scientific rigor, they have (1) challenged and debunked long-held biases (eg, drainage is mandatory after liver injury); (2) described innovative management strategies (eg, omental packing); and (3) provided scientific basis for practices that until very recently were strongly held opinions/biases, for example, packing for uncontrolled bleeding and most significantly, the superiority of non-operative management of all hemodynamically stable patients with liver injuries irrespective of grade. The field is richer for their contributions, and all of us who practice 'trauma surgery' owe a big debt of gratitude to Dr Fabian and associates.

On a personal note, Memphis is a unique place to train in the field of trauma surgery. All of us fellows who have trained there take pride in calling ourselves 'memphians'. For me it was the interaction, sometimes quite intense, that I witnessed and learnt from, between Drs. Croce and Fabian arguing over each word and punctuation in a scientific abstract. It taught me the importance of being able to identify the key elements/message that needed to be conveyed and to be able to convey it effectively in the fewest possible words. While the scientific interaction was a great learning experience, it was almost always on the very last day of getting the abstract in, and often meant a late-night trip, usually by one of the fellows to the FedEx hub at Memphis airport to get the abstract off on the very last flight. Outside of the Elvis Presley Memorial Trauma Center, it was the warmth with which all of us fellows were welcome at Dr. Timothy and Denise Fabian's home. When I had just joined as a fellow in July 1998, I was invited to Denise's annual Gumbo party. On realizing my parents were visiting, she invited them as well. My parents, now 94 and 89, have forgotten many things, but remember with fondness the graciousness extended to them by Denise Fabian.

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