

Yesterday, today, and tomorrow

Abdominal trauma management in America

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Charles Locke Scudder graduated from the Harvard Medical School in 1888, and began a long and illustrious career at the Massachusetts General Hospital when he started on the East Surgical Service as a house pupil in 1889. By 1891, Scudder had become a staff member as surgeon to the outpatient department. Young surgeons then, as now, were responsible for the initial care of surgical problems in the emergency room, so it is not surprising that, in the succeeding four years, he operated on three patients with penetrating stab wounds of the abdomen. He reported these in 1895 and, in true academic fashion, also tabulated for publication 53 additional abdominal stab wounds gathered from the literature.¹ All of Scudder's own cases recovered from the abdominal exploration, which was not the usual outcome of exploratory celiotomy in those days; admittedly, none of his patients had significant intraabdominal injury. By 1901, he had the opportunity to manage a patient who had his abdomen crushed between a train and the station platform. Scudder, in the classical conservative fashion, observed the man until a fecal fistula developed from a colonic perforation. He reported the case,² and after culling the literature he was able, in 1901, to publish one of the earliest collective reviews on blunt abdominal trauma.³ These were Scudder's first three papers. Though later in his career his primary interest was in the field of osseous trauma, abdominal injury certainly is an appropriate subject for a Scudder Oration.

Abdominal surgery—military origins

One hundred and two years ago Frederic S. Dennis wrote, "It is a source of national pride that laparo-



Charles Locke Scudder

tomy in penetrating wounds and visceral injuries of the abdomen was conceived, developed, and perfected in America."⁴ This operative care of abdominal injuries, however, was of comparatively recent occurrence. Surgery—classically, the care of wounds—always has been associated with military medicine. Armies originally had both a physician general and a surgeon general; but, recognizing the primacy in wartime of the care of injuries, only the latter title survived. The first American trauma surgery textbook, published in 1775, was by John Jones, one of the founders of the present College of Physicians and Surgeons in New York.⁵ As the frontispiece



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John Jones

says, it was "principally designed for the use of young military surgeons in North America." (The second edition in 1776, recognizing this Army bias, added "Naval Surgeons.") Military surgeons during the Revolutionary War, like most of the physicians in civil life at that time, rarely had any formal medical, much less surgical, training; almost no one had any previous experience with trauma. Illness during the 18th century was treated primarily by the clergy or by members of the government. Surgery was learned as a manual skill through apprenticeship. Jones' chapter on penetrating wounds of the thorax and abdomen is a short one. In it he taught that, "Wounds of the liver, intestine, kidney, pancreas, gallbladder, large vessels, spleen, mesentery, and stomach are only hazardous in proportion to the nature of the offices they perform in the animal economy and the degree of injury they have received." But perhaps anticipating our litigious society, he qualifies this statement by noting, "... to this must be added, errors committed by the patient or his physician by which greater degrees of fever, inflammation, and discharge are excited."⁵

Jones recommended only two surgical procedures for a gunshot wound, the removal of the ball or other extraneous material and the control of hemorrhage by ligature of the bleeding vessels. Specific management of intraabdominal organ injury was not even mentioned in his book because it was believed that incision of the peritoneum invariably would only provoke inflammation and suppuration with subsequent death. To this nonoperative approach for abdominal injury was added purging and enemata, which in considerable measure served to stimulate peristalsis. At the same time large amounts of opium or opiates were given, primarily for their antiperistaltic properties, in the belief that the wounded peritoneum, becoming inflamed, required rest for cure.

This "do nothing" approach to penetrating abdominal wall injuries continued in the early 19th century, including during the War of 1812. Amos A. Evans was surgeon on the USF *Constitution*. His casebook, following the *Constitution's* historic battle with the *Guerriere*, documented a single abdominal musket ball wound in an officer.⁶ Dr. Evans treated the patient by bleeding, enemas, strict antiphlogistic treatments, and cataplasms. The patient survived. It is of interest that, after his military service, this surgeon went to Harvard Medical School and became a physician.

Abdominal injuries in pre-Civil War America were managed in an identical expectant fashion, but protruding bowel could not be ignored; occasional case reports of their surgical care began to be published. In 1837, H. Tuck salvaged a six-year-old boy when he successfully reduced the uninjured eviscerated bowel after a scythe wound.⁷ In 1839, A.R. Kirkpatrick reported an ileal laceration caused by a wayward ax head that he managed by reduction of the protruding intestine, with fixation by suture, of the ileal wound to the abdominal wall. The patient survived and eventually closed the intestinal fistula, which the surgeon noted was "a wonderful example of the power of nature to overcome disease and injury."⁸

While there were numerous reports before the Civil War of eviscerated omentum and bowel treated by reduction, after enlargement of the penetrating wound, all of these were without evidence of visceral wounding. A spontaneous cure, however, was reported by Bartlett in 1856, following an abdominal gunshot wound caused by "the accidental discharge of one of Colt's revolvers. In the early evening of the

third day after the accident, while in the act of urinating, the ball escaped through the urethra and passed, suddenly, and with a 'click,' into the chamber-vessel."⁹

Certainly, it was not for lack of knowledge of abdominal operative techniques that celiotomy was avoided in abdominal trauma. By the middle of the 19th century abdominal section was well known, first having been described by Ephraim McDowell for ovarian disease in 1817.¹⁰ Anesthesia, after the report by Bigelow in 1846,¹¹ gained wide acceptance and all ovariectomies after the mid-century were done with inhalation anesthesia. Technical procedures were available. Lembert had been published regarding his serosal inverting stitch in 1826. Samuel David Gross, in his 1843 classic studies, "An Experimental and Critical Inquiry into the Nature and Treatment of Wounds of the Intestines," emphasized that "the proper treatment... is simply to sew up

the wound and to replace the bowel as speedily as possible... enterorrhaphy is, in itself, one of the most innocent of operations... it is folly to think of any other practice."¹² In an 1846 report on the progress of surgery, Blundell was quoted as believing that "the fears entertained by surgeons were greatly exaggerated respecting the dangers that attend wounds of the peritoneum." He observed that "inflammation in these cases, which is chiefly dreaded by the surgeon, in making extensive incisions through the peritoneum and in handling and exposing the abdominal viscera, is not so great as we have been taught to believe."¹³ George James Guthrie, in his lecture on wounds and injuries of the abdomen the following year, remarked in part that "purgatives should be eschewed in the early part of the treatment of penetrating wounds of the abdomen, the omentum when protruded is to be returned... and the intestine when excised to an extent exceeding



Surgical attending staff at King's County Hospital (late 1800s).

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the third part of an inch should be sewn up by continuous suture... A gunshot wound penetrating a cavity, if a wounded intestine can be seen or felt, its torn edges may be cut-off and the clean surfaces united by suture."¹⁴ He further noted that in a wound of the bladder an elastogum catheter should be kept in until the wound is presumed to be healed. Unfortunately, in keeping with his time, his final recommendation was that "the treatment of all these injuries must be eminently antiphlogistic, principally depending on general and local blood-letting, absolute rest, the greatest possible abstinence from food and, in some cases, from drink, the frequent administration of enemata and the early exhibition of mercury and opium in the different ways usually recommended with reference to the parts injured."¹⁴

And so armed with all this knowledge, we entered the most vicious and lethal conflict in North American history, and managed penetrating abdominal wounds with the same studied conservatism. This approach was described in 1864 by Frank Hastings Hamilton, professor of military surgery and fractures at Bellevue Hospital Medical College and the Long Island College Hospital.¹⁵ In a series of published lectures on gunshot injuries, which he based, in the main, on his experience as a medical inspector for the United States Army, he declared: "The patient should be laid in bed in such a position as to secure rest and relaxation of the muscles; the stomach should be kept empty and the bowels quiet with opium, warm fomentation should be applied and such antiphlogistic remedies employed as the circumstances may dictate." He cautioned, however, that "in no case ought the probe or the fingers to be introduced beyond or through the walls of the abdomen in search of foreign substances or for the purpose of determining the nature and extent of injuries." Hamilton concluded his lecture as follows: "Be assured, gentlemen, that the patient will have a better chance for life if you let him entirely alone; and it surprises me that any good surgeon could think otherwise."¹⁵

Sometimes, indeed, the conservative approach succeeded. In 1864, for example, Dewitt Peters, surgeon-in-charge of the Jarvis General Hospital in Baltimore, MD, admitted a young man 11 days after he had been wounded at Gettysburg. He wrote, "the abdomen was found to be greatly distended, tympanitic, and tender to the touch. Gentle pressure on



A.I. KELLER MASSACHUSETTS GENERAL HOSPITAL

First public demonstration of surgical anesthesia, Boston, October 16, 1846.

the abdomen caused gas and feces to escape freely out of the anterior wound showing that the ball had perforated the intestines. A catheter was introduced into the bladder when a slight amount of very offensive urine oozed out mingled with liquidated feces. Altogether his case was thought to be hopeless and I so informed him as I thought peritonitis of an aggravated form had set in."¹⁶ His treatment consisted of emollient poultices to the abdomen, injecting small quantities of flax-seed tea into the bladder, and giving full doses of opium and a diet of concentrated beef tea and mutton broth along with good nursing care. The patient improved, eventually closed his "artificial anus," and went back to duty.

George Alexander Otis in his enormous compendium, *The Surgical History of the War of the Rebellion*, pointed out that many other "recoveries" with this nonoperative approach may have been cases in which the peritoneal cavity was not entered or had simple penetration without injury of the viscera.¹⁷ While Otis noted "nature's almost divine power, even in wounds of the abdomen," overall they had a deplorable fatality with an 82 percent mortality in the 3,690 cases of abdominal penetrating-type injury that he recorded.

After the war, despite papers and lectures by

Samuel D. Gross, George Otis, Hunter McGuire, Robert Kinloch, and other noted surgical authorities, the anecdotal experience presented at surgical meetings and in the literature, and the comparative success of the ovariectomists, penetrating abdominal injury continued to be treated expectantly. The prolonged post-injury course and death of President James Garfield excited both popular and medical commentary; *Index Medicus* lists over 100 articles and editorials. The most vociferous advocate of laparotomy was James Marion Sims, who wrote a scathing commentary on the failure of the President's surgeons to explore him.¹⁸ In an acrimonious debate with James R. Wood at the New York Academy of Medicine, Sims advocated that surgeons caring for abdominal trauma should be as bold as the gynecologists by opening the peritoneal cavity, following penetrating wounds, for necessary visceral repair. These "Remarks on the Treatment of Gunshot Wounds of the Abdomen in Relation to Modern Peritoneal Surgery" quoted all the authorities, especially Gross from his *System of Surgery*.¹⁹ Sims declared that only by exploring the abdomen could the surgeon find the injuries that "should be remedied by suturing wounded intestine and ligaturing bleeding vessels," evacuating the body fluid and foreign effusions and closing the abdomen, using drainage or not, according to circumstances. Wood disagreed, noting that elective celiotomy for ovarian or uterine tumor was far different from an emergency procedure,²⁰ but the weight of surgical opinion logically was with the interventonists.

Unfortunately for logic, despite the application of Listerian principles of antiseptis, for the next few years all reported cases of abdominal exploration with wounded intestine died. Finally, in November 1884, William Tillinghast Bull, surgeon to the Chambers Street and New York Hospitals, deliberately by median section, opened the peritoneal cavity of a patient with a gunshot wound of the abdomen, repaired seven perforations in the small intestine and one in the sigmoid colon, and the patient survived.²¹ While Theodore Kocher in Europe several months earlier also had a survival after gastorrhaphy following a pistol wound,²² Bull's success electrified the American surgical world.

Each succeeding year brought an increasing number of case reports, and even small series, of deliberate exploratory laparotomy for gunshot, knife wounds, or the occasional abdominal contusion. In-

juries were repaired by enterorrhaphy or colorrhaphy. Nephrectomy or hepatic resection was accomplished with bleeding controlled with suture, packing, or actual cautery and even splenectomy was done deliberately. Lewis Atterbury Stimson, however, found only a 14 percent survival after exploratory celiotomy for gunshot wounds of the abdomen in New York City hospitals in the five years following Bull's successful case.²³ He contrasted that dismal salvage to a mere 54 percent mortality that was seen in abdominal gunshot wounds with symptoms, treated without operation in the same hospitals, in the preceding 10 years. He concluded that "either interference or noninterference should be the rule of practice, and the surgeon may be guided by his own convictions and feelings." It is not surprising, there-

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THE SYMPTOMS, THE DIAGNOSES AND THE INDICATIONS FOR TREATMENT OF ACUTE INTRA-ABDOMINAL INJURIES WITHOUT EXTERNAL EVIDENCE OF VIOLENCE

By JOHN B. DEAY, M. D., PHILADELPHIA.

Mr. President and Gentlemen, Members of the National Association of Railway Surgeons.—The honor conferred by your distinguished president, Mr. Murphy, in selecting me to deliver the address on surgery before this association is highly appreciated. I fear, however, that I am not able to do full justice to the occasion. The railways of the United States have increased such magnificent proportions that to do they far surpass those of any other land, both as to business and equipment. They represent more capital and employ more men than any other class of industries in this vast progressive land of ours, and we, as Americans, must feel a just pride in the accomplishment of such success. Your organization, therefore, represents the medical side of America's greatest industry, and you may be assured of the influence and opportunities for good which are afforded you. The success of your organization, like that of the railway itself, will be largely associated as largely with the conscientious and the practical management of your system.

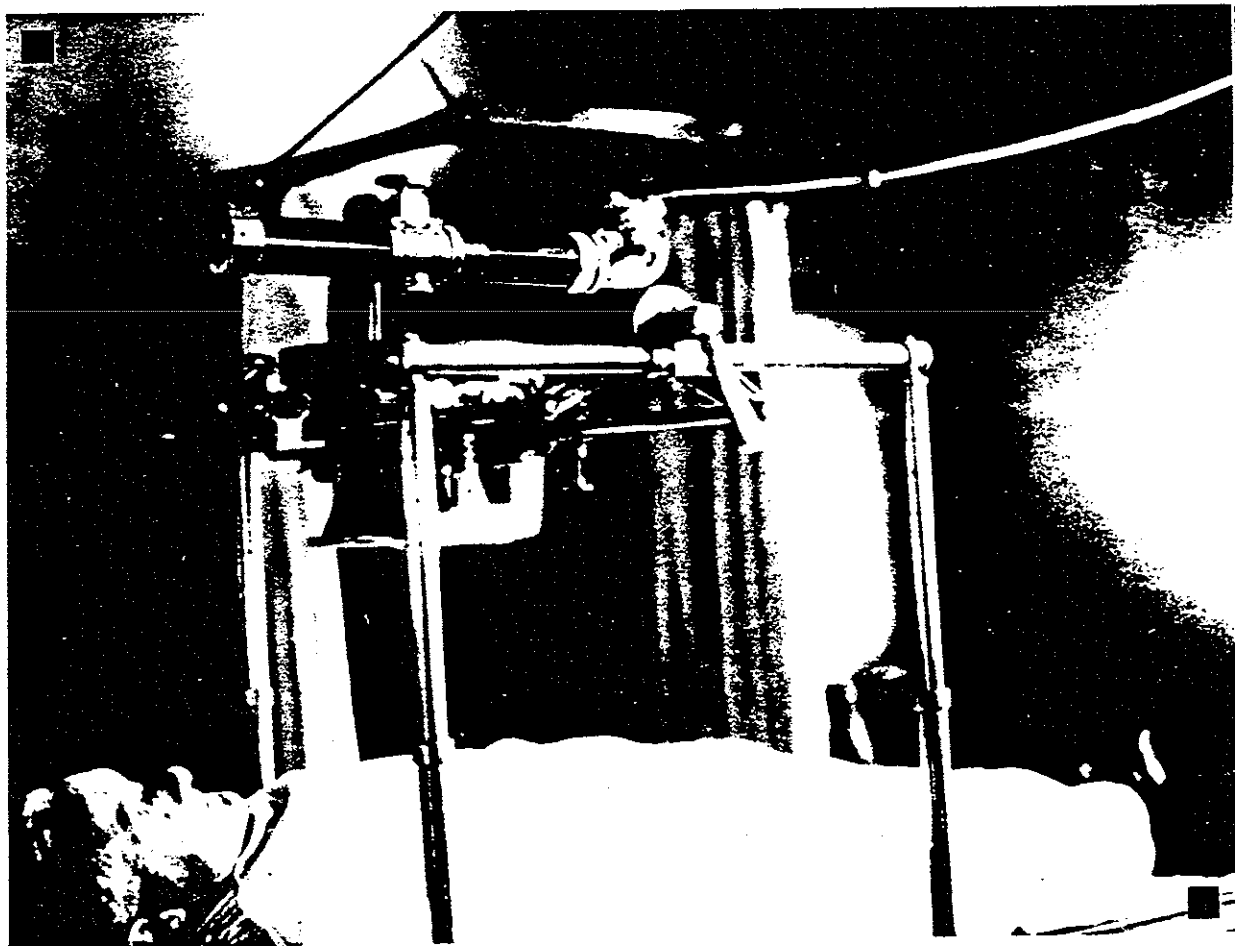
It is a pleasure to me to see in its relation to the railway industry the doctor with the surgeon, and to see that we have not finished our course. We have not finished our course, we have not finished our course, we have not finished our course. We must constantly strive to improve our methods to overcome the obstacles of the day. We give our time, our

fore, that during the Spanish-American War every soldier died following celiotomy for penetrating injury, while patients managed expectantly frequently survived.²⁴ William E. Parker, one of the staunch interventionists, asserted that, with lack of proper facilities, exploratory laparotomy should not be attempted in the field for wounds made by small modern bullets.²⁵

Blunt trauma, since no wound called attention to the abdomen, was, and remains today, a much more difficult problem. While high velocity impacts were rare in the last decade of the 19th century, abdominal contusion still generally was substantial. Many injuries were caused by equine and human kicks, striking against cart poles, or falling under their wheels, or as commonly reported, being crushed

between railroad car buffers. Railroad accidents at the turn of the 20th century appear to have been the mayhem equivalent of our current motor vehicle accidents. Many of the most distinguished surgeons in America presented reports on the management of abdominal injuries at the meetings or in the journals of the railway surgeons who, in fact, were the predecessors of the modern trauma surgeon.²⁶⁻²⁸

The collective reviews of penetrating trauma by Morton,²⁹ Markoe,³⁰ and Scudder³ each clearly indicated that if operative repair was to be successful it had to be done early. Scudder's review of blunt injury corroborated this axiomatic assumption. The early diagnosis of the need to perform abdominal section to repair injured intraperitoneal structures, therefore, became of paramount importance. Before



UPI/BETTMAN NEWS PHOTOS

An early X ray machine.

the use of celiotomy, the appearance of intestinal contents or gas or bile, while indicating serious intraperitoneal wounding, only reinforced the dismal prognosis. By the end of the 19th century it was acknowledged that these findings, when observed, were the only pathognomonic signs demanding exploration. Shock, generally characterized by the patients' facies and physical appearance rather than hemodynamic measurements, was acknowledged to be a highly variable and unreliable indication for operation. Rapid weak pulse and respiratory rate, similarly, were considered poor indicators of the need for celiotomy. Blood pressure, of course, was never mentioned because the sphygmomanometer was not developed until 1874, and did not come into popular clinical use in America until after the First World War.

Digital wound exploration for confirmation of penetration had been widely practiced, but enlargement of the penetrating injury for adequate evaluation usually was accomplished without any anesthesia; problems in accurate diagnosis, therefore, were frequent. By the 1890s probing of the wound, either with a finger or with an instrument, generally was viewed as bad technique, inaccurate, and dangerous.

Other techniques for ascertaining visceral injury were ingenious. Nicholas Senn demonstrated, both experimentally and clinically, that the insufflation of hydrogen into the rectum could, with reasonable rapidity, distend the entire intestinal tract.^{31,32} The escape of hydrogen through a bowel perforation could be detected by holding a taper to the gas escaping from the abdominal wound.³³ While this test was accurate for detecting injury to the gut, it never gained popularity, reportedly for fear of forcing feces into the peritoneal cavity through an intestinal wound that otherwise could be treated without operation.

Physical examination of the abdomen is notably absent from published case reports even into the 1890s. While "paresis of the intestine" leading to "tympanites" was recognized, abdominal auscultation never was mentioned until 1896, when John Benjamin Murphy, in discussion of a paper on abdominal contusion, authoritatively stated, "If the patient has perforation of the bowel, he has obliteration of peristalsis, which is one of the most positive signs of intestinal perforation."³⁴ John T. Rogers asserted, for the first time in 1898, that "extreme rigidity of the abdominal walls is perhaps the most



Nicholas Senn

important characteristic symptom" indicating the need for abdominal exploration.³⁵ The disappearance of "hepatic flatness" was called a presumptive but unreliable sign of gut perforation, since distended small intestine might mimic this finding.

Quantitative changes in the morphology of the blood, while observed at the turn of the century, were rarely used for diagnostic purposes. Joseph C. Bloodgood, in 1901, wrote that, "The examinations of blood after contusion of the abdomen to ascertain, if possible, whether we can distinguish by the changes in the elements of the blood the difference between shock from the injury alone, internal hemorrhages, and peritonitis from rupture, are not sufficient in number to allow any conclusions."³⁶ More than 30 years elapsed after that article before acute

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anemia or leucocytosis were recognized as presumptive signs of occult intraabdominal injury.

After the discovery of X rays in 1893, their use by surgeons was extensive, but primarily for evaluation of the extremities where immobility could be obtained for the long exposures required at that time. George Tully Vaughan reported the first diagnostic use of X rays in abdominal wounding in 1898. The skiagram finding of the ball in the abdomen after a thoracic gunshot wound prompted exploratory celiotomy and repair of a colonic and a renal injury. Vaughan concluded, "... recovery rapid, but large X ray burn developed on abdomen which required a year to get well."³⁷ Barium and bismuth evaluation of the gastrointestinal tract was begun in 1910, just before World War I. The radiographic appearance of pneumoperitoneum first was reported in 1915, and one year later noted as a pathognomonic X ray sign of intestinal perforation following penetrating injury. Air contrast study of the bladder showing an extraperitoneal perforation was described by Roger T. Vaughan in 1924.³⁸

Despite all these diagnostic advances allowing rapid selection for laparotomy, death was common following the operative management of both blunt and penetrating abdominal trauma. The 70 to 80 percent operative mortality generally recorded before 1900 was reduced with expeditious operation in the early years of this century to 50 to 60 percent from gunshot wounds, 20 to 35 percent death following celiotomy for stabbing, and 50 to 60 percent in operated blunt injury. Improvement in survival, however, seemed to plateau after the first decade of the 20th century, and gunshot wounds operated on during World War I had a 55 percent mortality. Even in postwar civil life, operated penetrating missile wounds resulted in a 45 to 60 percent death rate, and comparable results were reported in the early years of World War II. Operated nonpenetrating injuries in the literature between 1935 and 1942 noted only 50 percent survival.³⁹

Frank L. Loria pointed out in 1932 that 89 percent of the fatalities after exploratory celiotomy for trauma were due to hemorrhage and shock or from peritonitis.⁴⁰ It is understandable, therefore, that surgical results in torso trauma were markedly improved after the development of blood banks with the routine use of transfusion and with the start of sulfonamides and antibiotic usage. Forty-four years ago Herbert E. Sloane reported that when patients



Robert Hayward Kennedy

in the Johns Hopkins Hospital received appropriate transfusions and sulfonamides were used for peritoneal contamination, there was a more than six-fold decrease in stab wound mortality and a reduction to almost one-third in gunshot wound deaths following operation.⁴¹

The modern era

Finally, after the advances learned during World War II, the Korean conflict, and Vietnam, we enter into the modern era. Resuscitation, prevention and treatment of infection, and management of cardiorespiratory and renal failure, among other factors, have advanced by Mercurial leaps. Robert Hayward Kennedy's concept of a multidisciplinary trauma team advocated in his Oration on Trauma 23 years ago⁴² is today common reality, and reported mortality following stab wounds often is about one percent, with five to 10 percent overall death in abdominal gunshot wounds and less than 10 percent for treated blunt abdominal trauma.

Part of the improvement in survival undoubtedly is due to advances in transportation of the injured, anesthesia, antibiotics, and postoperative critical

care management; but in some measure these figures reflect our ability to select for operation only those patients who need surgical repair of injured intraabdominal and retroperitoneal structures. In 1947, Charles G. Rob first pointed out that soldiers with penetrating type abdominal wounds could be, and in many instances were, evaluated for abdominal exploration on the basis of clinical signs of peritoneal irritation.⁴³ Our own study in 1959 emphatically agreed with these conclusions, finding (in a prospective protocol for management of penetrating abdominal trauma, both stab and gunshot) that diligent repetitive evaluation of the abdomen could accurately discern the need for celiotomy without any evident increase in patient morbidity.⁴⁴

Many centers have confirmed the ability of well-trained surgeons to apply clinical indications in deciding the need for operation following abdominal trauma as they do with intraabdominal inflammatory disease. The majority of patients therefore are selected for operation on the basis of physical examination alone; it is for the minority who early do not exhibit their injuries that ancillary diagnostic techniques are needed.

Harold Neuhoff and Ira Cohen, in a classic paper in 1926, first described the use of peritoneal aspiration for the evaluation of intraperitoneal wounding.⁴⁵ Abdominal paracentesis was valuable if the aspirate showed blood, bile, or intestinal contents, but had no significance if there was a nonproductive tap. Thirty-nine years later, Harlan David Root and his associates defined a technique making aspiration of peritoneal fluid a simple but accurate invasive procedure that has gained universal acceptance in America.⁴⁶ His description of diagnostic peritoneal lavage in 1965 was a monumental milestone in our ability to assess with rapidity and accuracy the presence of intraperitoneal hemorrhage and/or bowel perforation. Crystal clear or faintly turbid lavage effluent without significant numbers of red or white cells indicates to all of us that celiotomy for intraperitoneal wounding almost certainly is unnecessary. Unfortunately, isolated or even massive retroperitoneal injuries are poorly evaluated by peritoneal lavage; but providentially, in 1977 the computerized tomographic X ray machine, developed in England, began to be used for abdominal trauma evaluation.⁴⁷ The anatomic axial sections through the abdomen produced by this device have given us a diagnostic ability to detect injury, especially in the

retroperitoneum, of a magnitude heretofore unknown, even often at exploration.⁴⁸ Finally, the development of angiography from its initial use in the extremities as described by Pearse and Warren⁴⁹ in 1931 began to be utilized in 1978 for the evaluation of intraabdominal and retroperitoneal bleeding,⁵⁰ and now is a standard method of recognizing hemorrhage from the retroperitoneum and the solid intraabdominal viscera and sometimes even stopping it.

The present methods of evaluation and treatment of both blunt and penetrating abdominal trauma have been spectacularly useful. Notable technical advances certainly include our ability to effect vascular repair or replacement rather than ligation. Surgical residents learn early on to use fine suture material, often with visual magnification in the meticulous techniques needed to control bleeding without obliterating vascular continuity. The availability of autogenous or off-the-shelf vascular grafts has extended our capability to restore organ or limb perfusion following major vascular injury. W.T. Bovie's development in 1924 of a machine for electrocoagulation allowed Harvey Cushing, almost exactly 62 years ago, to open a new era in tissue resection.⁵¹ Electrosurgical units today permit a rapid precise hemostasis unknown before that time, and together with modern hemostatic adjuvants, have simplified obtaining the classic surgical "dusty dry field," as well as enabling partial resection or repair of hepatic, splenic, and renal alterations.

The management of splenic injury in particular has seen a major change in operative treatment. In 1909, Walter Kirchner reported a series of splenic injuries treated with omental wrapping and suture control.⁵² While sporadic reports since that time treated splenic laceration by suture or packing, with the recognition of the deleterious effects following splenectomy,⁵³ surgeons rediscovered their ability to repair, rather than simply ablate, the injured spleen.^{54,55}

Techniques for the control of hepatic bleeding have been known for at least 80 years.⁵⁶ Currently, we not only can and do resect severely damaged areas of the liver, but major hepatic venous and intrahepatic caval injuries can be managed successfully. Our treatment of genitourinary trauma also has substantially improved with our ability to repair renal vessels, do partial nephrectomy or renal replantation after bench repair, manage ureteral in-

injuries percutaneously, or perform reconstruction of a bladder.

It is almost embarrassing to admit that a third-year surgical resident can perform a functional end-to-end small bowel anastomosis with a GIA stapler faster than I can hand sew a single-layer closed aseptic anastomosis. Only pancreatic and duodenal trauma still is difficult to routinely repair or resect, although the use of exclusion techniques for massive injuries and extensive drainage for those of lesser magnitude permit a far better survival than previously known.

The future

It was easy and fascinating to research the past, and the present is part of every academic trauma surgeon's milieu, but the future needs elucidation. To provide a balanced opinion, I wrote to many of my friends and colleagues asking for their prognostications of, or possibly their wishes for, what the next half century might hold in the management of abdominal trauma. One hundred and eighteen responded and the following is a consensus of where we may be in the year 2038.

The majority who expressed an opinion about etiology feel that blunt trauma, certainly blunt vehicular trauma, will markedly decrease with the advent of improved vehicular safety devices and anticollision sensors. Not to fear that we would lose experience, for most of these surgeons feel that penetrating trauma almost certainly will show a corresponding increase; a few optimists expect, however, that viable gun control laws also might decrease this interpersonal slaughter.

Almost everybody anticipates better diagnostic ability. More rapid, almost instantaneous, computerized tomographic scanning with improved resolution will be available, certainly in the emergency department, but possibly even in the operating room. As the patient enters the emergency treatment center, he passes through a multiple beam CT unit that will provide all the initial evaluation films that are required with a printout of the injuries perceived and their priority for management. Magnetic resonance imaging or PET scanning will be future diagnostic tools of immense importance, undoubtedly used to detect not only visceral and vascular damage but also ischemic or nonviable areas within solid and hollow organ systems. Many of my colleagues feel that sonography, which at present is widely used in

Europe, will be *the* superlative tool for on-scene evaluation of intraabdominal injury. In three-dimensional form it will be the routine non-invasive examination used by the surgeons within the emergency department and in the operating room. Specific injectable markers or tags will assess ongoing bleeding as well as detect gut perforation in a more sophisticated fashion than that used by Senn. Percutaneous probes often will determine both the location and the extent of these injuries and might accurately predicate the need for operation.

Almost without exception the trauma surgeons who responded to my inquiry feel that our diagnostic techniques will produce fewer exploratory celiotomies; in fact, the term *exploratory* will disappear, since the abdomen only will be opened for a specific purpose. Even when the need for repair is evident, many believe, or wish, that there will be percutaneous probes that can speedily and effectively produce hemostasis or repair damaged tissues through coherent light or sound without classic abdominal section. While this may sound fanciful others expect that special injectable substances will be available to control all bleeding, either when placed directly through angiographic catheters or possibly even when injected systemically.

If operate we must, many of the technical aspects of an operation will be done by robotics guided by the surgeon. Laser instruments will have replaced the knife and Bovie for incision and resection, and will provide wound hemostasis with minimal adjacent cellular injury. Tissue adhesives, or bonding epithelial or collagenous tissues, in most instances, will have superseded sutures for repair; certainly vascular glues will permit quick control of major bleeding and enable us to rapidly restore circulatory continuity. These will be supplemented by improved hemostatic agents; packing, if ever necessary, would be done with a biodegradable material that would not require re-exploration for removal. Preoperative identification of intrahepatic vena caval injury will allow the pre-celiotomy placement of a bypass atriocaval shunt avoiding the torrential hemorrhage currently encountered when the retrohepatic space is opened. If this does not suffice, vascular isolation with routine extracorporeal support of the proximal torso and head, extremities, and uninjured abdominal viscera will permit more leisurely and accurate repair. This, undoubtedly, will be augmented in severely-damaged organs by excision, bench re-

and replantation or, more probably, replacement from a readily available spare parts bank. In the event that the smaller institution does not have the needed organ available, replacement, at least for the immediate postoperative period, will be with miniaturized self-powered mechanical organs. These implantable devices also will be available for postoperative specific organ failure.

Finally, if bench repair is not feasible, and a spare part or mechanical replacement is unavailable, total body hypothermia with suspended animation will be used until organs are available. Such instant cooling also will be used on-scene in cases of uncontrollable massive hemorrhage when portable cardiopulmonary support would be ineffective.

Improved blood salvage with cell washers able to

separate infectious organisms from viable formed blood elements will be used, but banked blood transfusion will have disappeared. Having passed through the hypertonic saline phase, the ultimate volume replacement solution will be a genetically engineered warm fluid with clotting factors, artificial platelets, and oxygen-carrying capacity, possibly an improved stroma-free hemoglobin, that will not disable the reticuloendothelial system. Volume replacement will be aided by specific adjunctive therapies, such as thromboxane synthetase inhibitor, complement activation modulators, or free radical scavengers. Pain will be controlled by electromagnetic blockade of selected pain impulses rather than by systemic narcotics. There will be a non-noxious super detergent available to wash out the abdomen



An early ambulance belonging to Beth-El Hospital (now Brookdale).



Modern-day surgeons using visual magnification for meticulous work.

that incorporates an enzyme inhibiting adhesions.

Basic science research will have advanced the "physiology of survival." Specific agents, viruses, or antibodies will be used to counteract infectious organisms that will have eliminated the general use of antibiotics. Monoclonal reagents, or exchange transfusion, will bolster host defense and will be used in conjunction with narrow range antibiotic substances. There will be an improved ability to manipulate or moderate the immunologic response with T-cell up-regulators and macrophage/neutrophil enhancers. We will probably use monokine inhibitors to control the deleterious effects of inflammation and inject other agents to control post-injury hypermetabolism. Growth factors or specific enzymes will be given to stimulate healing and organ regeneration, and there will be improved injury-specific nutritional support substances to speed restoration of the anabolic process.

Finally, as anticipated, computers will be used to

assess everything from the injury history down to specific organ metabolic turnover; prioritizing each step of the resuscitation, evaluation, and patient treatment, including operation. These machines with artificial intelligence will, in real time, evaluate performance quality and any errors will be corrected by moderate suasion on the surgeon. Admission scanning of the human genome for genetic risk factors will be able to predict and initiate early treatment to prevent multiple organ failure.

Thus, we will reach a surgical nirvana where we will be able to salvage almost everybody with abdominal trauma. While I believe that most of these prognostications are not pipe dreams, I have a more disturbing future fear. I'm afraid that all the advances in selective nonoperative trauma management or percutaneous techniques for control of bleeding and repair will increase the clamor of emergency physicians, pediatricians, and internists to have primary responsibility for abdominal trauma

care. Surgeons, enamored only of operative procedures, will abandon their responsibility to initially manage the injured patient until celiotomy actually is needed. I fear a time will come when the patient will be resuscitated, evaluated, and treated by a *trauma physician*, and all the wonderful non-or minimally invasive procedures that stop bleeding, repair tissue defects, irrigate and cleanse the coelom, and prevent or treat organ failures will be carried out by these physicians or by interventional radiologists, intensivists, or tissue repair technicians. Only if these measures do not suffice will the surgeon be called and told where and what needs excision or gluing up. Following the operation the intensivist will speed the patient through recovery to rehabilitation. One of my colleagues even feels that in the future, the surgeon—like Dr. Amos Evans—will graduate and become a pharmacologist, and all operations will be done by physicians' assistants.

We already see premonitory signs of our voluntary regression back to mere manual technicians. Neurosurgeons, now, refuse admission to their service of patients not requiring craniotomy. Orthopaedists consult but don't accept multiple extremity injured patients when operation is inappropriate for their fractures. General surgeons today are willing to let emergency physicians resuscitate, evaluate, and initially care for their injured patients because it's convenient. Scudder, in his paper on abdominal contusion, noted that patients without abdominal wounding were difficult problems. "There being no external wound, the physician is first summoned" (and here today, of course, we may read the emergency physician or the pediatrician). "Upon him rests grave responsibility for the mortality in these cases is very great; deplorably great. Many cases," he cautioned, "are fatal if left to themselves and the physician." This is the identical problem we face today and for the future.

It is alleged that medical care is cognitive, surgical care merely procedural, but operation is not synonymous with surgery. As residents, Clarence Dennis taught us that surgery was that branch of medicine where operation was but one of the therapeutic alternatives. After the presentation of the paper on "Selective Conservatism in Abdominal Trauma," we were accused of abandoning surgery. Only a surgeon, however, after evaluating the traumatized patient and all of the treatment possibilities, can de-

cide *not* to operate when it is appropriate for the injuries. The American Board of Surgery and the Residency Review Committee in Surgery acknowledge the importance, during the training period, of the management of multiple trauma patients who are not operated upon. Surgeons in America, despite the advances in nonoperative management, must never abandon the injured patient to other medical disciplines. Trauma, especially abdominal trauma, clearly is and must remain a surgical disease. 11

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