# A Better Mousetrap

Blood spurts as from a geyser, and prompt action is required. With its familiar hiss, suction is applied, and an expanding redness comes into view, like a vermilion Carolina moon waxing in accelerated time. The knob is turned, and a satisfying muffled click is felt more than heard. Warily, the vacuum is released and the knuckle of once gushing mucosa, now ensnared with a shiny black rubber ring, recedes slowly from sight like the jettisoned stage of a spacecraft. Another bleeding varix, temporarily staunched only weeks ago with a styptic injection, has finally been successfully obliterated (Fig. 1)[1].

It seems a little surprising now that the occurrence of esophagogastric varices in cirrhosis and their propensity to bleed became widely appreciated only late in the history of hepatology, after the turn of the 20th century.[2] Although modern estimates do range widely, we know that the prevalence of varices in cirrhosis, their risk of bleeding and rebleeding and the consequent mortality, are all in the 20% to 80% range, depending upon the variables in the study and the particular stratification used.[3] Nonetheless, William Osler, who recognized the existence of esophageal varices[4] and had himself witnessed a fatality therefrom,[5] had personal experience of only two cases by the time he published his famous textbook in 1892, in which, forsooth, he also wrote that hemorrhage from gastric varices was seldom fatal.[6] The existence of esophageal varices had actually been clearly established 50 years earlier, in 1840, by William Power of Maryland, who reported on the autopsy of a 50-year-old man of robust frame, intemperate habits, and deficient intelligence.[7] The patient, who died of gastrointestinal hemorrhage, was found to have "Varicose veins of the oesophagus" that Power had never met with before, nor had he found a similar case recorded. Power wondered, ". . .whether the presence of varices to such an extent, and death caused by their rupture, be not-something as yet unheard of in pathological anatomy."[7] Power's discovery was later confirmed in a report from France,[8] but even so this was still the only experience of that entity for Friedrich Theodor von Frerichs, the founder of modern hepatology, by the time his own textbook was written.[9] Admittedly it was well nigh impossible then to diagnose in life the presence of varices—silent or otherwise—in the years before Adolf Kussmaul performed the first really practical esophagoscopy in Freiburg in 1868, using an endoscope designed for the urethra and bladder by Antonin J. Désormeaux of the Académie de Médecine in Paris, and with the skillful cooperation of his intrepid first subject, a visiting sword swallower who was performing at a local inn.[10] The development of flexible fiber-optic endoscopy by Basil Hirschowitz and others in the 1950s,[11] culminating in the first reports of its clinical use, initially in May 1961,[12,13] conveniently expanded the patient pool to include less-supple individuals (than Kussmaul's itinerant showman), for whom this procedure would be feasible, thereby illuminating the way for the endoscopic evaluation and treatment of varices that we enjoy today.

Preble's report,[2] at the beginning of the 20th century, of 60 patients with cirrhosis and fatal gastrointestinal bleeding, of whom 80% had esophageal varices, foretold an era of intensive investigation of portal hypertension[14] and a demand for effective therapies to combat this most lethal complication of cirrhosis, either by decompressing the portal system and/or diverting variceal blood flow elsewhere[15] or simply by obliterating the varices in the hope that the problem would go away. From the mid 1940s, and for the longest while, shunt surgery was king, with its peak popularity in the 1970s followed by the development of selective shunts and devascularization procedures in the next decade or so, because of dissatisfaction with the morbidity of surgically induced encephalopathy and liver failure. With the growth of successful liver transplantation and the development of nonsurgical methods for treating bleeding varices, enthusiasm for shunt surgery has been tempered in favor of pharmacological, endoscopic, and interventional radiological treatment, while selective shunts are reserved for patients with good liver function (especially those with portal hypertension without cirrhosis) and, in some cases, shunts and devascularization procedures may be used when other treatments fail.[17-20] In this context, the idea of obliterating varices rather than bypassing them with a surgically created shunt dates back more than 50 years to a case report that described simultaneous variceal suture ligation and injection with a sclerosing solution at thoracotomy, through an esophagus that had been split open almost from stem to stern, from the level of the aortic arch to the diaphragm.[21] Thereafter, the techniques of vascular shunting, sclerotherapy, and ligation evolved along parallel (and occasionally intersecting) paths, each with its fervent advocates vying for the favors of patients with portal hypertension and varices that had bled or were doomed to do so.

Surgeons began to divert the flow of blood from the portal to the systemic circulation in patients with portal hypertension, even before they fully understood the dis-


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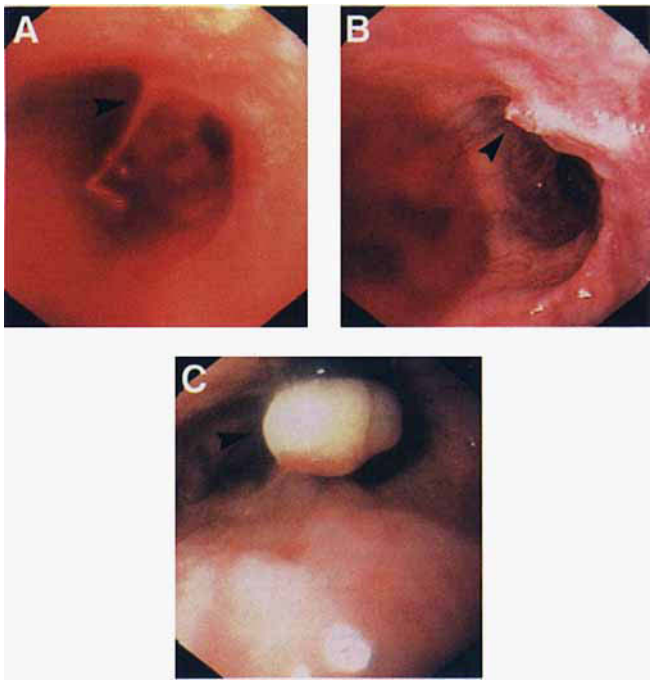


Fig. 1. Bleeding esophageal varices. (A) In an endoscopic photograph of the esophagus of a 56-year-old alcoholic man with massive hematemesis, blood can be seen spurting from a ruptured varix (**arrow**). (B) After injection sclerotherapy of the variceal trunk and immediate hemostasis, the source of bleeding was revealed as a white nipple, which represents what was thought to be a fibrin-platelet plug (**arrow**). Endoscopic variceal ligation was performed for recurrent bleeding from the same source three weeks after the initial episode. (C) The white object (**arrow**) is the remnant of a banded varix. Reproduced with permission from Navarro and Reuben.[1]

ease and its complications of ascites and variceal hemorrhage that they hoped to cure.[16] Portosystemic shunts were performed in patients in the early part of the 20th century, in the years before the First World War—based on the surgical anastomosis between the portal vein and the inferior vena cava in dogs, described by Nikolai Vladimirovich Eck in Moscow in 1877[22]—to replace the then-fashionable operation of splenectomy that was combined with the curious procedure of omentopexy, in which the omentum was sewn to the parietal peritoneum to produce portosystemic collaterals.[16] That William Mayo strongly favored splenectomy (as did Harvey Cushing and William Halsted before him) and omentopexy, and that 7 of Eck's 8 canine patients died of the operation (while the survivor was allowed to run away by a careless technician)[16] did not dampen the enthusiasm of pathfinding shunt surgeons in those days. Interest in Eck's fistula was revived by Archibald McIndoe, as a result of his detailed pathological vascular studies in cirrhosis in the late 1920s,[15] and the idea was enthusiastically and variously adapted by Allen Oldfather Whipple and his many disciples at Columbia-Presbyterian in New York City,[23] who incidentally also pioneered temporizing balloon tamponade techniques for acute variceal bleeding.[24] From the 1970s to the 1990s, total portal decompressive shunts gave way to selective shunts and eventually to partial portal shunts, using graded interposition conduits.[25] For a while it seemed that there were countless ways for surgeons to bypass varices and/or decompress the portal venous system, as they used all of their anatomical ingenuity. Unfortunately, while the need to prevent variceal bleeding by surgery was well fulfilled, all such operations, in greater or lesser measure, were wanting with respect to patient morbidity, due to encephalopathy and liver failure, and mortality. Physicians desired better overall results for their patients and not just the cessation of hemorrhage. And as historian, philosopher, and guru of invention Henry Petroski theorizes, it is the *desire* to improve on the failings of existing technology that drives innovation and not simply that there is a need to innovate.[26] Want, says Petroski, and not necessity, is the mother of invention. This principle and its corollary that no invention is perfect and that everything is susceptible to change and improvement in time is very well exemplified by the successive and continuing innovation in the treatment of portal hypertension and variceal bleeding.

The desire to create a portosystemic shunt and yet avoid the deleterious effects of surgery, usually but not exclusively expressed by nonsurgeons,[17] gave rise to the familiar radiologically created transjugular intrahepatic portosystemic shunt (TIPS) that is ubiquitous today.[27] First achieved crudely by dragging a Grüntzig balloon, inflated in the portal vein, through liver tissue to create a track to the hepatic vein,[28] the predictable failure of this early method due to track closure has been remedied, partially at least, by deploying a metal conduit between the portal and hepatic veins[29–31] as predated by experimental efforts in dogs more than 30 years ago.[32]

Variceal sclerotherapy has passed through many iterations too, since the first description of an endoscopic approach by a thoracic surgeon and otolaryngologist in 1939 who used an quinine-uretan sclerosant and an idea borrowed from the treatment of rectal hemorrhoids.[33] Although later the percutaneous transhepatic approach to both sclerotherapy[34,35] and variceal embolization[36] was short-lived, the technique of endoscopic sclerotherapy progressed from using a rigid esophagoscope or fiber-optic endoscope with a flexible oversheath, both under general anesthesia,[37] to performing the procedure electively or in an emergency with an unmodified modern video endoscope under conscious sedation, using any one of the many sclerosants available,[38,39] including cyanoacrylate in some countries.[40] Despite the exceptional success of endoscopically delivered injection sclerotherapy in control-

ling acute variceal hemorrhage and the achievement of a significant reduction in bleeding recurrence,[41] this form of variceal therapy has its shortcomings too, in terms of patient morbidity. Sclerotherapy can produce mucosal ulcers that bleed, esophageal stenosis, the rare case of esophageal perforation, and other unpleasant misadventures such as adult respiratory distress syndrome, bronchoesophageal fistula, chylothorax, pneumothorax, and mediastinitis.[38] Besides, brandishing a naked needle loaded with sclerosant in the vicinity of a bleeding varix that must be speared, no more than a fingerbreadth from the heart, lungs and great vessels, in a bucking patient, is not for the faint-hearted. By the mid 1980s, the moment was ripe for another leap forward in variceal therapy. This came as the exquisitely simple but effective remedy of endoscopic variceal band ligation that was first published in 1988 in two landmark articles[42,43] from the Mile High City of Denver, not far from the Rocky Mountains in the Centennial State of Colorful Colorado.

Compared to the many innovations over the years of surgical and radiological portosystemic shunting, sclerotherapy, and pharmacotherapy for portal hypertensive variceal bleeding, there had been little progress in variceal ligation since the surgical operations of the 1950s, except that ligation could be accomplished via a small rather than large esophageal incision by pulling on the pliable mucosa to bring the varices into view from both the esophagus and stomach.[44,45] Even in the early 1970s, ligation was still being performed surgically for acute variceal bleeding, with good results for Child-Turcotte-Pugh Class A patients and moderate success for Class B patients, but almost certain demise (90% mortality) for Class C patients, who also suffered the morbidity of fistulae at the esophageal suture line more frequently (20%) than the other patients.[46] Like Clarence Crafoord and Paul Frenckner 50 years before him,[33] Gregory Van Stiegmann, then Assistant Professor of Surgery at the University of Colorado School of Medicine (where he is now Professor of Surgery and Associate Dean and Vice-President for Clinical Affairs), was inspired to improve the treatment of esophageal varices while gazing at rectal hemorrhoids that he was treating. Stiegmann had had considerable experience with endoscopic esophageal sclerotherapy from his training in surgery and surgical endoscopy during a brief sojourn in Cape Town, South Africa. He wondered whether the nonoperative rubber-band ligation procedure that he was using on the hemorrhoids, and that had superseded sclerotherapy for that purpose, could be adapted to treat esophageal varices too. By producing a "suction polyp" of the pliable esophageal mucosa to "grasp the varix," so to speak, he reasoned that it should then be possible to apply the ligating rubber bands in the esophagus. Using personal funds accrued from consulting fees, Stiegmann commissioned engineers of the machine shop at the University to fashion a stainless steel ligator, consisting of an outer cylinder and an inner cylinder, which was screwed onto the tip of an endoscope instead of its lens cap (Fig. 2A, 2B).[47] Using a single latex "O" ring and a trip wire, the efficacy of Stiegmann's gadget was first established using a canine model of varices.[42] Then he and John Goff, a colleague and friend in the Division of Gastroenterology in Denver, showed that the procedure was feasible, safe, and effective clinically by performing 132 varix ligations during 44 separate sessions in 14 consecutive patients under topical anesthesia and/or conscious sedation, using an over-tube and a single-fire technique.[43] In the 10 patients who completed the course of treatment (2 died of unrelated causes and 2 were noncompliant), all achieved complete variceal eradication after a mean of 3.9 sessions, and there were no major complications. These excellent results were subsequently borne out in numerous studies thereafter by Stiegmann[48] and others,[49] and superiority over sclerotherapy was established. True to Petroski's predictions, the Stiegmann-Goff technique has been modified to improve performance and reduce failures due to complications, such as trauma caused by the over-tube[50] that was needed for the single-fire device. Translucent plastic ligators that fit snuggly over the tip of the endoscope have been developed, with repeat-fire capabilities[51] that obviate the need for repeated intubation and the use of an over-tube. Incidentally, Stephen Perry of the rubber manufacturing company Messrs Perry and Co., London, England, would have been gratified to learn that Stiegmann has extended the utility of the rubber band, which he invented originally to hold papers or envelopes together and patented in 1845.

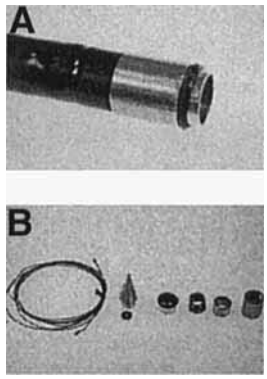


Fig. 2. (A) The original endoscopic ligating device. The instrument was carved from stainless steel and screwed onto the endoscope in place of the lens cap. A single black rubber "O" ring is shown in place over the distal end of the device. (B) The trip wire and the components used to assemble and load the ligator. Photographs generously provided by the inventor, Dr. Greg Van Stiegmann.

Endoscopic variceal ligation is now recommended by many authorities[38,41,52,53] as first-line treatment for bleeding esophageal varices and to prevent rebleeding. Its widespread

use has not been adopted yet, possibly in part due to the cost of the disposable equipment,[39] which local ingenuity in some less-affluent parts of the world has overcome by using what the authors describe as indigenous substitutes.[54] By substituting bands used for hemorroidal ligation and fashioning an introducer (to slip the "O" ring on the cylinder) from a glass pipette and a tripwire from the wire used to string tennis raquets, the authors saved thousands of rupees.[54] The next logical step in this saga will probably be to recommend prophylactic banding to prevent the first hemorrhage,[55,56] although for some doubters the notion of this motion is still controversial.[57] "If a man can write a better book, preach a better sermon or make a better mousetrap, than his neighbor, though he build his house in the woods, the world will make a beaten path to his door." Whether or not these words were ever uttered or written by the American essayist, poet, and philosopher Ralph Waldo Emerson is still a matter for conjecture,[58] [a] but the sentiment that quality prevails in the marketplace is clearly true for Stiegmann's invention. Parenthetically, it must be noted that the Patent Office has issued over 4,000 mousetrap patents, although none have surpassed the quality of the trap invented by John Mast of Lititz, PA, in 1899.[59] Whereas a path may not have been beaten to Greg Stiegmann's door, partly because his invention has never really been eponymous and partly because of the high altitude of his mountainous retreat, it is unquestionably one of the better traps that has yet been devised to ensnare that most elusive mouse, the bleeding esophageal varix.

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[a] *While this sentence has never been found in Emerson's works, he is believed to have used it in a lecture either at San Francisco or Oakland, California, in 1871.* Borrowings *was an anthology compiled by women of the First Unitarian Church of Oakland, and Sarah Yule contributed this sentence, which she had copied from an address years before. There has been some controversy because others, including Elbert Hubbard, have claimed authorship. (Source: Respectfully quoted: a dictionary of quotations requested from the Congressional Research Service. Edited by Suzy Platt. Washington: Library of Congress, US GPO, 1989.)*

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