Pulsatile Irrigation in Orthopedics

Jonathan W. Sobel, MD
Victor M. Goldberg, MD

ABSTRACT: A brief history of the use of irrigation fluids in the management of traumatic and surgical wounds is presented. The development of irrigation fluid as a debridement technique and some of the problems in controlling the fluid dynamic parameters are described. Orthopedics requires varied applications of irrigation devices, and a machine has been developed which combines irrigation lavage or pulsatile debridement technique with the rapid suction removal of effluent. The applications, technique, and precautions in using a Rapid Suction Removal System are described.

Introduction

Irrigation of traumatic wounds is a time-honored and established technique that is documented early in the history of medicine. The ancients recognized the value of irrigation and debridement as a method of reducing the potentially fatal complications of infection following traumatic wounds. In the first era of irrigation treatment of wounds, the fluid itself was used as a vehicle for carrying away foreign material, contaminated debris, and necrotic tissue that was debrided with either instruments or the surgeon’s hand. It was not until Lister’s era that the value of antiseptic solutions was recognized. Practically and conceptually, this marked a new era in the management of wounds since the irrigant was used as a vehicle to bring antiseptic solutions into the wound in order to exert a direct antibacterial effect. The value of antibiotic solutions as irrigating solutions has been well documented in recent times. Irrigating fluids, with antibacterial components such as polymyxin B, bacitracin, and/or neomycin are currently used routinely in reducing the incidence of postoperative infection in clean surgical wounds. Thus developed the concept of prophylactic antibiotic wound irrigation.

Recently, the value of using the irrigant fluid as a debridement mechanism has been realized. This concept was initially carried out by increasing the height from which the irrigant was poured over the wound to increase the pressure or force of the irrigant fluid. More recently, the fluid source, usually an intravenous fluid bottle, was raised to again increase the gravity effect. An alternate source of fluid pressure was sought, and the first mechanical irrigating machines were fluid pumps that delivered a sterile irrigating fluid at a constant pressure. However, it was discovered that if the fluid were pulsed to create individual droplets, the fluid itself would have a mechanical action of debridement on the surgical surface. The earliest use of jet lavage was in oral surgery and dentistry, where pulsatile irrigation was used in the oropharynx and on diseased gum-tooth interfaces.

Pulsatile irrigation was a substantial improvement in wound management when compared to previous gravity-fed systems or hand held bulb syringe lavage. Experimental evidence documented the ability of pulsatile jet lavage to reduce bacterial contamination of wounds and its effectiveness in the debridement of necrotic tissue from crush wounds. The parameters that affected the type of debridement produced by the pulsation source were then defined. The chief parameters were the frequency of pulsations and the pressure of the delivered fluid. These were measured in pulses per second (pps) and pounds per square inch (psi), respectively. Finally, the total volume of the fluid delivered was a product of these two parameters.

Some problems existed in controlling these parameters, and a machine was developed to regulate the frequency of pulsation, which subsequently affects the size of the fluid droplet delivered to the wound, and careful pressure monitor controls were developed to similarly protect and control the fluid delivered. Finally, the development of fluid debridement machines required a more sophisticated method of effluent recovery and disposal. Pulsatile irrigation can cause substantial spraying and rebound of the delivered fluid, in addition to delivering an increased volume of fluid. Therefore, a built-in suction system was designed to remove the irrigant fluid with the debrided material.

Orthopedists have utilized irrigation in a variety of ways, primarily because of the diversity of the clinical applications and the clinical problems encountered in this subspecialty practice. For example, in the trauma field, the orthopedic surgeon often sees a combination of soft tissue and bony injuries with extensive areas of foreign material embedded in the tissues. The typical example is that of a motorcycle accident where the victim is severely abraded by the road surface. This “road rash” often not only destroys the superficial and subcutaneous tissues, but may also abrade through both cortical and cancellous bone while
concurrently packing these tissues with asphalt. Treatment of this type of traumatic injury requires exhaustive debridement of the soft and bony tissues. Open fractures are mandatorily debrided and irrigated in an attempt to reduce the threat of osteomyelitis. Established osteomyelitis may require multiple debridements and irrigations on separate occasions. Osteotomies which use oscillating or reciprocating saws may produce bone debris in the soft tissues which requires irrigation. Elective orthopaedic procedures also utilize irrigation fluid which contains antibiotics as a prophylactic measure to reduce postoperative wound infection. Finally, in total joint surgery utilizing cemented endoprostheses, the bony trabecular surface is carefully prepared and debrided to remove the marrow contents to provide a bed for good mechanical interlock between the cement and bone. Thus, orthopedists require an irrigation tool that can provide irrigation fluids in all three modalities: lavage, antibiotic solutions, and debridement of both soft and bony tissues. Immediate rapid removal of effluent containing bone debris or contaminated tissue is needed to prevent the spreading of osteogenic potential material or bacteria into adjacent tissue. The parameters of pulsatile irrigation must be carefully controlled so that the higher pressures and frequencies of irrigation used with bony tissues can be adjusted to more gentle frequencies and pressures that are required for soft tissues.

**Description of System**

The Pulsavac Pulsatile Lavage Debridement System (Snyder Laboratories, Dover, Ohio) is a machine consisting of a main unit which is pole mounted, and runs on 120 volts AC current, creating its own suction, and having its own effluent containers (Fig. 1). This irrigation instrument integrates a variable pulsatile lavage and constant flow irrigation with surgical suction removal of effluent. The pulsatile lavage mode provides intermittent fluid flow at pressures from 1 psi to 69 psi at flow rates of up to 1000 ml per minute and at 8 pps to 40 pps. The surgical suction mode, which works with the irrigation system, produces a partial vacuum from 1 ml to 300 ml of mercury at a maximum air flow rate of 45 liters per minute at the suction pump. The irrigation mode was designed to provide constant fluid flow at a variable rate from 1 ml to 400 ml per minute. The hand control set is connected to the main machine through a long set of clear plastic tubes. The control set has several nozzles with different configurations (Fig. 2). One of the nozzles has a large orifice to be used for suction and lavage, while another one sprays at a 90° angle in preparing the intramedullary canal for endoprosthetic cementing (Fig. 3). Using the machine is uncomplicated, and the technique is similar in both trauma and total joint applications. Prior to the start of the case, the irrigant fluid bags are hung on the side of the machine, and the hand control sets and tubing are placed on the sterile field in a plastic bag. While the conventional suction and electrocautery lines are being passed from the sterile field, the sterile tubing is similarly passed off and connected to the machine.

**Applications**

The Department of Orthopedics, University Hospitals of Cleveland, has had experience over the past three years with this new irrigation instrument. We have used this machine for all open fractures, procedures which produce large amounts of bone debris and, for the past 2½ years, in every cemented total hip and knee replacement. In this latter application, the machine was used both for bony debridement as well as soft tissue lavage. This machine has been utilized in over 350 total joint procedures and in over 250 open fractures. In the trauma application, the wound is irrigated in a traditional fashion using the lavage mode of the machine with gentle manual debridement of the soft tissues. After the contaminated bone ends are isolated and identified, the machine is turned to the pulsatile irrigation and debridement mode and the bone ends are debrided. In addition, caution is used not to direct the debridging fluid stream directly at the soft tissues, since the pressure and frequency of pulsation may be high enough to inject the irrigating fluid into the superficial portions of the soft tissues (45 psi/20 ppm). If, on inspection, the bony ends still appear to have impacted foreign material, a rongeur or curette is used to remove this material using a standard technique and the pulsatile debridement is repeated. Finally, the bone ends and wound are lavaged with an antibiotic solution of bacitracin and polymyxin B. The rationale for this sequence of irrigation terminating with an antibiotic solution is based on studies indicating that brief exposure to these solutions is effective, and also the expense in using them solely for debridement is prohibitive. The surgical portion of the procedure is then completed.
In the total joint replacement applications, the set-up is similar. However, the intramedullary canal tip is utilized for the debridement of the intramedullary canal surface when needed. The surgeon instructs the unscrubbed circulator to adjust either the frequency of the pulsation or the pressure with which the fluid is delivered (Fig. 4), depending upon the condition of the trabecular surface of the bone. Often, the bone of the rheumatoid patient who has been on steroids is extremely fragile and lower operating pressures and pulsations (15 psi/15 psi) are required to debride and clean the bony surfaces in anticipation of cementing. Excessive operating pressures/pulsations in osteoporotic bone may result in severe bone loss. In total knee replacement, the femur, patella, and tibia are sequentially debrided, and the suction mode is then used alone to dry and remove irrigant from the inter-trabecular spaces.

Discussion

Rapid recovery suction combined with pulsatile irrigation-debridement marks a new development in the fluid management of traumatic and surgical wounds. Complex wound management in orthopedics requires a versatile approach to tissues of varied morphologies. The immediate suctioning and removal of effluent in concert with the pulsatile system provides a more effective debridement than a simple pulsatile fluid alone. We have described this effect as Rapid Recovery Suction (RRS). RRS is the simultaneous suctioning and irrigation of a surface in which the irrigation fluid outlet, surface being prepared, and suction portal are in such close proximity so as to contain and simultaneously remove the effluent generated by the process (Fig. 5). We believe that in total joint replacements, the bone surfaces are more rapidly and effectively prepared because of the RRS effect. In trauma applications, the RRS process contains the effluent and reduces the chance of the cross contamination of neighboring clean tissues. In the uniform application of this technique of pulsatile debridement suction to the cancellous bony surfaces in total joint replacement, it has become apparent that the cancellous surface is meticulously debrided of the marrow and fat elements, which has improved bone-cement interlock. This has been a substantial improvement over the previous simple irrigation-preparation techniques.

In dealing with the traumatic wounds frequently produced in high energy motor vehicular accidents, this irrigation-suction system has proved particularly helpful, in that it can be adjusted between modes of lavage and pulsatile debridement, as well as
providing sensitive controls for frequency of pulsation, pressure, total volume delivered, and suction recovery vacuum. During the past three years, we have found this system to be more effective than simple irrigation in the fluid management of traumatic wounds, elective surgery, and total joint replacement. Some caution must be employed, however, in not applying the pulsation debridement mode to soft tissues with too high a pressure, or the irrigant fluid may inadvertently be superficially injected into the soft tissues. Similarly, pressures and pulsations must be reduced when debriding osteoporotic bone in total joint replacement.

With reasonable prudence, however, tissue injury does not occur. Finally, operator judgment must be applied in selecting the optimum frequency of pulsation and pressure of the delivered fluid, so as to obtain the optimum combination for debridement of different tissue morphologies.

References