Vacuum-Assisted Closure for Sternal Wounds: A First-Line Therapeutic Management Approach

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Background: Vacuum-assisted closure therapy has gained widespread use since its introduction in 1997. Previous studies have attributed significant benefit to its use for treatment of sternal wounds with or without mediastinitis. Management of sternal wounds with this therapy has been shown to decrease the number of dressing changes, reduce the time between débridement and definitive closure, and reduce costs associated with a protracted course of in-hospital dressing changes. The therapy has been used both as a bridge between débridement and definitive closure and as a catalyst to secondary sternal-wound healing.

Methods: The authors performed a retrospective review of 103 patients who underwent vacuum-assisted closure therapy after median sternotomy between June of 1999 and March of 2004 at a single institution. The wounds were classified as sterile wounds, superficial sternal infections, and mediastinitis. The wound closure device, consisting of a polyurethane sponge and evacuation tube with in-line suction, was applied sterilely to all wounds over a layer of Acticoat.

Results: Vacuum-assisted closure was utilized in the treatment of sternal wounds for 103 patients (67 male patients and 36 female patients) whose mean age was 52 years (range, 3 months to 91 years). Patient comorbidities included diabetes, chronic obstructive pulmonary disease, end-stage renal disease, immunosuppression, and others. Sixty-four percent of the patients had a diagnosis of mediastinitis; 36 percent had either superficial infections or a sterile wound. The therapy was utilized for an average period of 11 days per patient. Sixty-eight percent of the patients (70 of 103) had definitive chest closure with open reduction internal fixation and/or flap closure. The remaining 32 percent had no definitive closure method. The overall mortality rate was 28 percent (29 of 103 patients), although no deaths were directly related to use of the therapy, and only four deaths resulted from sepsis as a consequence of mediastinitis.

Conclusions: The authors report the largest series of patients treated with this therapy for post-sternotomy sternal wounds and believe it is safe and effective as a first-line therapy in the management of sternal wounds. The mortality rate from their study represents the patients' underlying disease process and comorbidities and is not a reflection of complications associated with the therapy. Vacuum-assisted closure therapy has been shown to decrease wound edema, decrease the time to definitive closure, and reduce wound bacterial colony counts. The authors have implemented the therapy for most patients with sternal wounds/mediastinitis at their institution, and believe it should be a standard protocol in the first-line management of these types of wounds. (*Plast. Reconstr. Surg.* 116: 1035, 2005.)

Sternal wounds are a major complication of cardiac surgery, the most devastating of which

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is the development of a post-sternotomy mediastinitis. Reported incidences of this complication range from 0.5 percent to 10 percent; however, post-sternotomy mediastinitis may be extremely debilitating and is often fatal, with mortality rates reported between 10 and 20 percent.[1] The variation in the reported incidence and mortality rates is closely correlated with pre-existing patient comorbidities, namely diabetes mellitus, chronic obstructive pulmonary disease, and end-stage renal disease.[2,3]

To reduce the morbidity and mortality of such sternal wound complications, therapy algorithms were devised and have evolved. Previous algorithms consisted of early and aggressive débridement of the wound, an extensive period of one to two times per day of wet-to-dry dressing changes that would aid in cleaning and contracting the wound leading to the eventual definitive closure of the wound by vascularized flaps such as pectoral-muscle, rectus-muscle, or omental transpositions.[4,5] While this method worked, it was often tedious, time-consuming, and inefficient. The daily dressing changes are painful, causing significant discomfort to the patient.

The advent of the Vacuum-Assisted Closure device (Kinetic Concepts International, San Antonio, Texas) in 1997 has vastly improved the management of chronic wounds.[6,7] The device consists of a polyurethane foam dressing connected to a vacuum source and collection canister through an evacuation tube. The setup allows for subatmospheric pressure to be applied to the wound, thereby increasing local blood perfusion, increasing the rate of granulation tissue formation, and decreasing bacterial counts and edema in the wound.[7] The device is currently indicated for chronic wounds such as stage III or IV pressure ulcers; however, mounting data have shown it to be effective in sternal wounds by decreasing the time to definitive closure, decreasing the number of dressing changes, and also decreasing the cost of hospital stays.[8,9] We have previously shown vacuum-assisted closure therapy to be an effective bridge between débridement and definitive closure of cardiac sternal wounds, and as a sole therapy for the treatment of mediastinitis.[8]

The current study assesses the effectiveness of the system as either the sole or adjunctive therapy in the largest reported cohort of patients with postcardiac surgery sternal wounds or mediastinitis. This series further validates the safety of the therapy for sternal wounds.

Patients and Methods

A retrospective review was conducted to analyze the effectiveness of vacuum-assisted closure therapy for the treatment of sternal wounds between June of 1999 and March of 2004 at the University of Chicago Hospitals. Data obtained from the medical records included demographic information, medical comorbidities of the patients, type of sternal wound, length of time the therapy was in place, method of definitive wound closure, and mortality rate.

All sternal wounds were the result of patients undergoing a median sternotomy procedure. Wounds were classified into three categories: superficial, sterile, or mediastinitis. The majority of the sternal wounds evaluated were classified as mediastinitis, which was defined as an acute infection of superficial and deep tissues to the sternum with purulence usually occurring within 1 to 4 weeks of the cardiac procedure. The rest of the sternal wounds were either superficial (involving the tissues anterior to the sternum) or sterile (resulting from the inability to close the median sternotomy because of patient instability or primary closure compromising heart integrity). Patients with these wounds were then brought back to the operating room after they were deemed medically stable to undergo surgery.

As the mainstay of wound therapy, the sternal wounds were initially surgically débrided of all devitalized tissue, promoting the ingrowth of healthy, viable tissue. Adequate débridement was determined by the presence of healthy vascularized tissues and the absence of foreign bodies and purulence. Any wound cultures that were taken intraoperatively were used to direct the choice of antibiotic coverage. The wound closure system was then applied to the defect under sterile conditions over an antimicrobial layer of Acticoat (Smith and Nephew, Largo, Fla.). In addition to its antibacterial properties, the Acticoat layer helped to prevent ingrowth of tissue into the sponge. After appropriately shaping the sponge and achieving a seal, negative pressure of 125 mmHg was applied via the in-line suction tubing. A pressure of −50 to −75 mmHg, just enough to deflate the sponge, was applied to all pediatric patients. The first change was done on postoperative day 2; subsequent changes were every 48 hours thereafter. Finally, the timing and method of definitive closure were based on the appearance of the wound and medical stability of the patient. Not all wounds required definitive closure. Small wounds and rapidly granulating and contracting wounds were allowed to close secondarily, with the therapy acting as a catalyst to closure. These patients were equipped with a portable closure device and home nursing was initiated for sponge changes.

RESULTS

Sternal wound treatment was provided to 103 patients (67 male patients and 36 female patients) with an average age of 52 years (range, 3 months to 91 years). Of the sternal wounds treated, 64 percent were diagnosed as mediastinitis, while the remaining 36 percent had either superficial infections or sterile wounds. Vacuum-assisted closure therapy was utilized for an average period of 11 days per patient (Table I).

Definitive closure of these sternal wounds was utilized in 68 percent of the patients and included open reduction with internal fixation ($n = 12$), flaps ($n = 34$), or a combination of the two ($n = 24$). The remaining 33 patients (32 percent) had no definitive closure method. Open reduction with internal fixation was accomplished by sternal plating using titanium plates and a 2.4-mm SternaLock system (Walter Lorenz Surgical, Jacksonville, Fla.) in adults and absorbable plates in our pediatric patients. Flaps included the pectoralis major and omentum. Eighteen of the 33 remaining patients with no definitive closure died. The wounds of the remaining 15 patients were allowed to close secondarily, with the therapy acting as a catalyst. Table I provides the breakdown of closure methods.

TABLE I
Patient Data

Age	3 mo to 92 yr (mean, 52 ± 26 yr)
Sex, no. of patients	
Male	67
Female	36
Diagnosis, no. of patients (%)	
Mediastinitis	66 (64)
Sterile wound	21 (20)
Superficial wound	16 (16)
Closure method, no. of patients (%)	
Omental transposition	3 (2.9)
Pectoralis flap	31 (30.1)
ORIF	12 (11.7)
Combinations	24 (23.3)
No definitive closure	33 (32)
Length of VAC usage, days	2–79 (mean,11)
Mortality, no. of patients (%)	29 (28)

ORIF, open reduction with internal fixation; VAC, vacuum-assisted closure therapy.

Minor complications of chronically draining wounds and incisional breakdown were seen in 10 percent of the 70 patients undergoing definitive closure. All of these minor complications were treated nonsurgically. Of the patients requiring flap closure who survived, none required a second flap or re-operation.

Of the 103 patients undergoing vacuum-assisted closure therapy, there were 29 deaths (28 percent). These 29 individuals (18 male patients and 11 female patients) ranged in age from 3 months to 91 years (Table II). Twelve of these patients had three or more comorbidities as listed in Table III, seven patients were between the ages of 3 months and 5 years, and four patients underwent a cardiac transplant procedure. Of the different diagnoses, 13 patients were classified as having mediastinitis, 12 as having sterile wounds, and four as having superficial wounds. The majority of these patients had no definitive closure ($n = 18$), while six were closed with flaps, two by open reduction with internal fixation, and three by a combination of both open reduction with internal fixation and flaps. The causes of death of these 29 patients varied from pneumonia to pulmonary emboli (Table II). However, only four patients (3.9 percent) died from sepsis secondary to mediastinitis and all four patients were identified as having positive blood cultures before our intervention. No deaths were directly related to use of the closure device.

DISCUSSION

Post-sternotomy mediastinitis is a dreaded complication. Despite new techniques in sternal closure, patients with post-sternotomy mediastinitis have significant morbidity and mortality rates, which can be as high as 20 percent.[1] The treatment of sternal wound infections has changed over the past four decades. In the late 1960s, Payne and Larson[10] described the technique of wound débridement, primary sternal closure, and mediastinal irrigation. In the 1980s, sternal wound management evolved with the use of vascularized flaps to fill the dead space.[1,4,5] Regardless of the early methods of closure, wound débridement was paramount in the initial management.

TABLE II
Mortality Breakdown

Patient	Age (yr)	Sex	Closure Method	Diagnosis	+ Blood Change	3+ Comorbidities	Transplant	Cause of Death
L.B.	8 mo	M	No definitive closure	Mediastinitis	Y	N	N	Pneumonia
S.B.	34	F	No definitive closure	Superficial	Y	N	N	Acute pericarditis
T.B.	76	F	Flap	Sterile	N	N	N	Cardiac failure
L.B.	76	F	Flap	Mediastinitis	Y	Y	N	Sepsis
R.B.	78	F	No definitive closure	Sterile		Y	N	Cardiac failure
O.C.	75	F	No definitive closure	Superficial	N	N	N	Cardiac failure
T.D.	23 mo	F	No definitive closure	Sterile	N	N	N	Cardiac failure
J.D.	77	M	No definitive closure	Sterile	N	Y	Y	Cardiac failure
C.F.	48	M	ORIF/flap	Mediastinitis	Y	Y	N	Aortic rupture
J.G.	13 mo	M	ORIF/flap	Mediastinitis	N	N	N	Neurologic devastation
L.G.	4	M	Flap	Mediastinitis	N	N	N	Respiratory failure
J.H.	64	M	ORIF	Sterile	N	N	Y	Cardiac failure
E.H.	61	M	ORIF/flap	Mediastinitis	Y	N	N	Traumatic aortic rupture
C.K.	70	M	No definitive closure	Mediastinitis	N	Y	Y	Hemorrhage
D.L.	5 mo	M	No definitive closure	Sterile	N	N	N	Respiratory failure
I.L.	50	F	Flap	Mediastinitis	N	Y	N	Respiratory failure
R.L.	81	M	ORIF	Superficial	N	Y	N	Cardiac failure
R.M.	81	M	Flap	Sterile	N	Y	N	Cardiac failure
M.M.	31	M	No definitive closure	Sterile	N	Y	N	Neurologic devastation
C.M.	72	M	No definitive closure	Mediastinitis	Y	N	N	Sepsis
B.M.	68	F	No definitive closure	Mediastinitis	N	N	N	Pulmonary embolism
J.M.	3 mo	M	No definitive closure	Sterile	N	N	Y	Sepsis
J.O.	40	M	No definitive closure	Superficial	N	N	N	Cardiac failure
M.R.	91	M	No definitive closure	Mediastinitis	N	N	N	Pneumonia
B.S.	62	M	No definitive closure	Sterile	N	Y	N	Cardiac failure
L.S.	50	F	No definitive closure	Mediastinitis	Y	Y	N	Sepsis
B.S.	5 mo	F	No definitive closure	Sterile	N	N	N	Cardiorespiratory failure
M.S.	51	M	Flap	Mediastinitis	N	Y	N	Cardiorespiratory failure
R.S.	81	F	No definitive closure	Sterile	N	N	N	Cardiac failure

ORIF, open reduction with internal fixation.

Adequate débridement of all involved and devitalized tissues, including bone, is essential to initiate the healing and recovery process.[11–13] Different authors have advocated various débridement methods, including serial-staged and single-radical.[8,11] We prefer a method of precise controlled débridement of only devitalized tissues, allowing for the possibility of sternal salvage with rigid plate fixation.[14]

TABLE III
Patient Comorbidities

Comorbidities	Frequency (%)
Pulmonary	
Congenital	2 (1.9)
COPD	16 (15.5)
Cardiovascular	
Congenital	17 (16.5)
Endocarditis/pericarditis	6 (5.8)
Cardiomyopathy	5 (4.9)
CAD	65 (63.1)
CHF	14 (13.6)
Renal	
Insufficiency/failure	6 (5.8)
ESRD	11 (10.7)
Autoimmune	
Transplant	11 (10.7)
Connective tissue	5 (4.9)
Hypertension	42 (40.8)
Diabetes mellitus	37 (36)

COPD, chronic obstructive pulmonary disease; CAD, coronary artery disease; CHF, congestive heart failure; ESRD, end-stage renal disease.

With the advent of the vacuum-assisted closure in 1997, Morykwas and Argenta introduced a means of increasing blood flow, increasing rates of granulation tissue formation, and decreasing tissue bacterial counts in complex wounds.[6,7] Support for the use of the therapy in the management of sternal wounds has been documented in a number of small series. Mendez-Eastman[9] reported a case of the therapy used in combination with a vascularized flap for sternal wound management. Obdejin et al.[15] evaluated three patients in whom the therapy was used to treat post-sternotomy mediastinitis. In their series, vacuum-assisted closure therapy made it possible to avoid the need for a vascularized flap. Tang and colleagues[16] reported their results utilizing the therapy in 15 patients with varying degrees of post-sternotomy sternal wound infections. They had excellent results in all surviving patients.

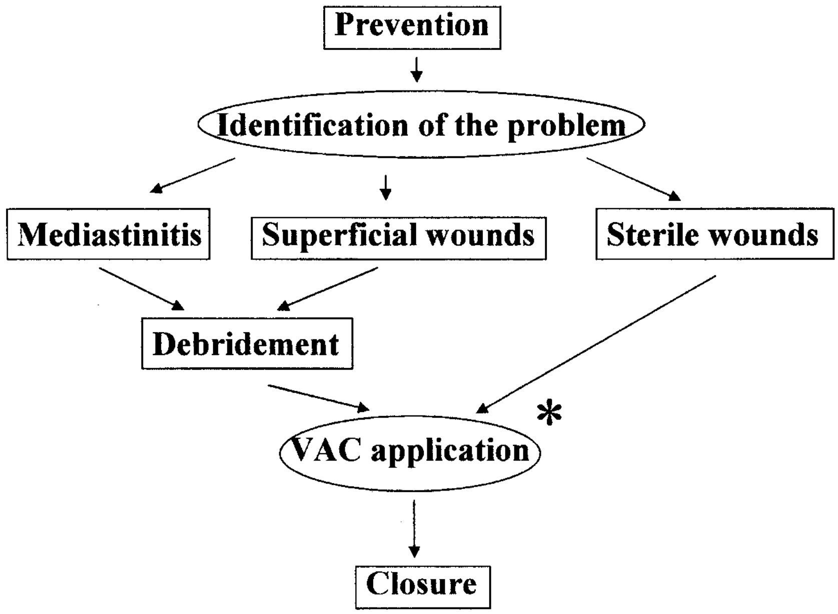

FIG. 1. Sternal wound management algorithm.

We have previously reported the superiority of the therapy versus traditional twice-daily dressing changes for sternal wounds at our institution.[8] We found that the therapy significantly lowered the number of overall dressing changes in the already-debilitated patient with mediastinitis. Its use also decreased the number of flaps needed for reconstruction of the sternal wounds and was found to be an excellent bridge between débridement and definitive closure, decreasing the number of days between the initial débridement and closure. The efficacy of vacuum-assisted closure in the management of sternal wounds has been supported subsequently by other authors.

We have since compiled data on the largest cohort of patients having been treated with the therapy for the management of post-sternotomy sternal wounds. Our data suggest that vacuum-assisted closure has been successful both as sole and adjunctive therapy in this patient population. This has allowed a substantial number of patients to avoid an additional operation for definitive closure. Fifteen patients (14.6 percent) did not undergo definitive closure and were allowed to close secondarily. Our technique of precise and controlled débridement in conjunction with the therapy also allowed for sternal salvage and open reduction with internal fixation in 35 percent of our patients. This is particularly valuable in preventing subsequent sternal breakdown in high-risk patients.[17] Vacuum-assisted closure has proven to be a safe and effective method for managing sternal wounds.

Despite our high mortality rate of 28 percent, there were no vacuum-assisted closure-related deaths or complications. In 2001, Kirsch et al.[18] reported a 35 percent mortality rate in patients with mediastinitis. Twenty percent of our mediastinitis patients (13 of 66) died. We attribute this high number to the severity of illness of our patients and their multiple comorbidities. Twelve of the 29 patients (41 percent) had three or more comorbidities. In addition, our population included 19 patients (18 percent) between the ages of 3 months and 14 years with congenital cardiac anomalies and associated syndromes. We also included 11 patients (11 percent) who had undergone cardiac transplantation. This group of patients has extremely high baseline mortality rates. Only four patients (3.9 percent) died from sepsis as a consequence of mediastinitis. Each of these patients had positive blood cultures at the time of their presentation. Perhaps if the disease process had been identified at an earlier stage, these patients would have had a different outcome.

Subatmospheric dressings have been scrutinized for both efficacy and safety. This is especially true for sternal wounds when placing negative pressure over the heart. Our study has helped to further evaluate the role of the therapy in these complex wounds. We conclude that the vacuum-assisted closure is both safe and effective both as a sole therapy and as an adjunct to definitive closure of the sternum in post-sternotomy wounds. We found no closure-related deaths or complications. None of our patients who were closed had flap failure or required re-operation. We attribute this success in part to the therapy's ability to prepare the wound bed and maintain a low bacterial count in a healthy granulating bed.

Vacuum-assisted closure has proven to be effective in the management of a spectrum of sternal wounds. With superficial wounds, it can obviate the need for a second closure operation, it affords more comfort to the patient by reducing the number of dressing changes, and it was useful in the management of sterile wounds as well. This group included unstable patients whose chest was not closed secondary to cardiopulmonary compromise. The therapy played an intermediary role while these patients were stabilized and brought back to the operating room for definitive closure. Therefore, we believe that vacuum-assisted closure has found a new place in the treatment algorithm for complex sternal wounds (Fig. 1) and should be thought of as a first-line therapeutic tool when dealing with this patient population.

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