Wound Closure in Nonidiopathic Scoliosis: Does Closure Matter?

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Background: Postoperative wound complications after posterior spinal fusion are difficult to manage. The incidence in the nonidiopathic patient population is significantly higher than the adolescent idiopathic population. A comparison of wound complications after posterior spinal fusion for nonidiopathic scoliosis between the utilization of the orthopaedic surgical team at the time of closure performing a nonstandardized wound closure versus a plastic surgeon with a plastic multilayered closure technique and rotational flap coverage when needed had not previously been evaluated. The purpose of this study was to compare the complication rate between nonstandardized and plastic multilayered closure of the surgical incision in patients undergoing posterior spinal fusion for nonidiopathic scoliosis.

Methods: The charts of 76 patients with a primary diagnosis of scoliosis associated with a syndrome or neuromuscular disease and who underwent a posterior spinal fusion were reviewed. Forty-two patients had their incisions closed using the nonstandardized technique and 34 using the plastic multilayered technique. These 2 groups were compared for age, sex, primary diagnosis, number of levels fused, estimated blood loss, number of units transfused, operating room time, wound complication, and return to operating room.

Results: The wound complication rate in the nonstandardized closure group was 19% (8/42) compared with 0% (0/34) in the plastic multilayered closure group ($P = 0.007$). The unanticipated return to the operating room rate was 11.9% (5/42) for the nonstandardized closure patients versus 0% (0/34) for the plastic multilayered closure patients ($P = 0.061$).

Conclusions: The use of the plastic multilayered closure technique in this patient population is important in an effort to decrease postoperative wound complications. The ability of the surgical team to decrease the infection rate of nonidiopathic scoliosis cannot be overstated. The method of wound closure plays a major role in lowering this incidence.

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Postoperative wound infection places a significant burden on the patient, family, and treating physician along with a significant cost burden on the medical system.[1] Financial burden is realized with subsequent treatments such as skilled local wound care, intravenous antibiotics, and additional operative intervention. These surgical sequelae include irrigation and debridement, removal of implant, and complex wound closure including muscle flaps. Little is written or taught about spinal wound closure. Should the paraspinal musculature be reapproximated? How do we deal with fascial closure and/or lack of available fascia? The overall rate of complications associated with spinal fusion in nonidiopathic scoliosis population is higher than the idiopathic population, with reports ranging from 24% to 75%.[2–4] Primary diagnosis and comorbidities can influence the rate of spinal wound infection considerably, but this rate is consistently higher than the adolescent idiopathic population. The overall rate of infection after posterior spinal fusion ranges from 4% to 23% in patients with neuromuscular and dysraphic conditions.[2,5–16]

The use of muscle flap closure has been previously described as a treatment for complex or infected spinal wounds.[17] Since 2009, we have increasingly involved plastic surgeons specifically trained in spinal wound closure at the time of index surgery. The role of closure of the surgical incision primarily has not yet been investigated. We hypothesize that this plastic multilayered method of closure is associated with a lower risk of postoperative wound infection after posterior spinal fusion in patients with nonidiopathic scoliosis compared with nonstandardized wound closure.

METHODS

We performed an IRB-approved retrospective chart review of all posterior spinal fusions performed at our institution by 2 orthopaedic surgeons since 2007. The patients were identified from their medical records by

CPT (common procedural terminology) codes 22842, 22843, and 22844 and then identifying the patients' primary diagnosis. For all cases beginning in 2009, we have involved a plastic surgeon specifically interested in the spinal wound at the time of the index procedure to assist in wound closure and postoperative wound management. The primary endpoint was acute postoperative wound complication requiring additional hospitalization. An acute postoperative wound complication was defined as one occurring within the first 6 months postoperatively. A secondary endpoint was an unanticipated return to the operating room for irrigation and debridement of the surgical wound within the first 6 months. Patient's age, sex, primary diagnosis, number of levels fused, estimated blood loss, number of units of packed red blood cells transfused, operating room time, and outcome were recorded. Inclusion criteria were patient age of 8 to 25 years at the time of the index procedure, a primary nonidiopathic diagnosis, and a minimum of 18 months of follow-up. Exclusion criterion was previous back surgery before the index procedure. We identified 76 consecutive patients who met our inclusion criteria, 42 in the nonstandardized closure arm and 34 in the plastic multilayered closure arm. All patients underwent a posterior spinal fusion, 7 of the patients also underwent anterior spinal fusion/release. One patient had a staged procedure.

Nonstandardized closure was routinely a fascial, subcutaneous, and skin closure performed by orthopaedic surgeon. No flaps were performed in this group. We termed the closure performed by the orthopaedic surgeon, as opposed to the plastic surgeon, as "nonstandardized" because there were several surgeons involved and there was not a formalized technique.

Plastic multilayered spinal wound closure involved a layered technique (Figs. 1A–F). The first layer, the deep layer, was considered as the level of the paraspinal musculature. For the most part, the paraspinal muscles were in contact with the spinal implant and bone graft. In isolated cases of iliac fixation, U-shaped gluteal muscle flaps were advanced for vascularized coverage of the iliac component of the implant as well as providing volume/padding for prevention of soft-tissue erosion (Fig. 2). As the paraspinal muscles are segmentally perfused and prone to areas of ischemia, they were mobilized on lateral perforating vessels and then medially advanced to ensure vascularized coverage of the operative site. This layer is not fluid impermeable. The muscles are freed from the tethering effect of the midline fascia and are allowed to fall below the plane of the spinous processes. Even in cases where the muscle is at times replaced with fatty tissue, such as spina bifida and muscular dystrophy, a layered closure can still be performed with available muscle, investing fascia and fascia. A deep Jackson-Pratt drain, deep to the paraspinal muscles, provided the negative pressure for the vascularized fill of the dead space by the mobilized muscles.

The second layer separated the deep compartment from the superficial compartment and functioned as a barrier layer. This layer is fluid impermeable after closure. The closure was often fascia-to-fascia, but occasionally, due to lack of true fascia, the investing fascia of either the trapezial or latissimus musculature was utilized. For iliac fixation, the investing fascia of the mobilized gluteal muscle was used. At times the mobilization of the trapezial muscles with the rhomboid complex or the latissimus muscle was required for recruitment of tissue for soft-tissue voids or to prevent tension at the fascial midline closure. A second Jackson-Pratt drain was placed in the superficial space above the fascial closure.

The third layer included the remaining soft tissue. Potential risk factors for edge ischemia were addressed: previous lateral scars, simultaneous other approaches for exposure, tension on closure, among others. No sutures were placed in the subcutaneous fat.

Postoperatively, the removal of the superficial drain was based on rate and volume of drainage. The primary goal of the deep drain was the vacuum effect for soft-tissue fill of dead space. The deep drain was typically removed first. In the absence of a CSF leak, the deep drain was removed at day 3 or 4 depending on the patient's mobility, that is, if the patient is up and around then it is removed at day 3. The superficial drain was removed when the drainage is <30 to 40 mL per 24-hour period. The superficial drain is never left in >10 days no matter what the drainage. If the superficial drain is removed with >40 mL/day, then a seroma may develop. This was rarely aspirated. If there was increased drainage, an abdominal binder was placed at the time of superficial drain removal or before.

Statistical Analysis

All continuous variables (age, number of levels fused, estimated blood loss, number of units transfused, and time in the operating room) for the 2 groups were compared using the t test for independent variables. Dichotomous variables (sex, presence of wound complication, and return to the operating room) were analyzed with the Fisher exact test. Odds ratios were determined for wound complication and return to operating room. The χ^2 test was used to compare the frequencies of various diagnoses. Diagnoses were considered as an independent group if they comprised at least 5% of the total study population. For statistical analysis purposes, the subjects were grouped into (1) cerebral palsy, (2) familial dysautonomia, (3) Prader-Willi syndrome, (4) paralytic scoliosis, (5) muscular dystrophies, and (6) other. For all analyses, $P < 0.05$ was considered significant. Statistical analyses were performed with SPSS software Version 10 (Chicago, IL).

RESULTS

The 2 groups were similar in terms of age, number of levels fused, estimated blood loss, number of transfusions required, and time in the operating room (Table 1). In addition, iliac fixation and the allograft used were similar for the 2 groups. The frequencies of the primary diagnoses are presented in Table 2. Cerebral palsy was the most prevalent diagnosis in both treatment arms. Any diagnosis

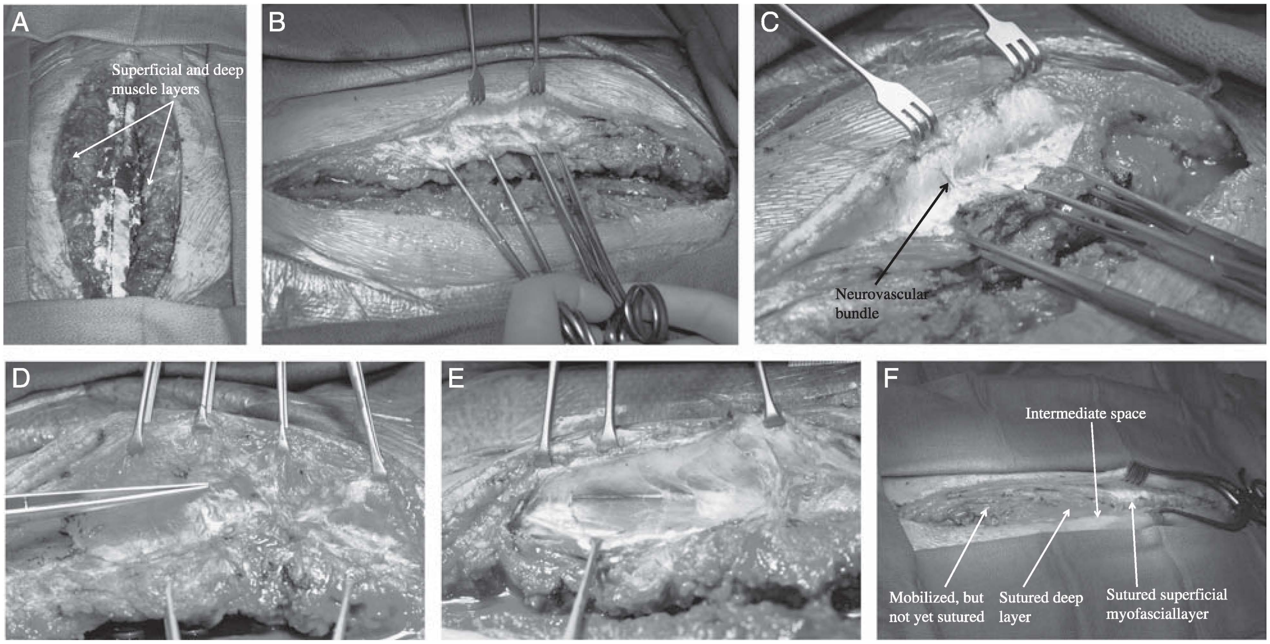

FIGURE 1. A, After completion of instrumentation with bone grafting. B, Mobilization of the fascia/superficial layer. C, Fascial layer dissection with preservation of perforating segmental blood vessels demonstrated with the forceps. D, Rhomboid dissected en bloc with trapezial myofascial complex. E, Isolation of deep muscle layer. F, Loose closure (approximation) of the underlying muscle with tight closure of the fascial layer.

with <4 patients was included in other. The distribution of sex (45.2 vs. 44.1% female, $P = 1.0$) and primary diagnosis ($P = 0.633$) were not significantly different for the groups.

Eight of the 76 subjects had acute wound complications necessitating treatment. All patients were in the nonstandardized closure arm, yielding a wound complication rate of 19% (8/42). The wound complication rate in the plastic multilayered closure arm was 0% (0/34). This difference was statistically significant ($P = 0.007$, Table 3). The odds ratio for a wound complication in the nonstandardized closure arm was 10.2. A post hoc power analysis was performed for this primary endpoint and was found to be 0.83. For the secondary endpoint, 5 of the 42 patients (11.9%) in the nonstandardized closure arm and none in the plastic multilayered closure arm (0/34) required a return to the operating room for irrigation and debridement. The return to the operating room occurred at an average of 9.8 ($\pm$ 8.1) days after the index procedure. No patients were indicated for implant removal. This finding trended toward significance ($P = 0.061$, Table 3). This may represent type II error as our study was not powered to determine significance at this endpoint. Cultures were obtained in all patients who returned to the operating room for an irrigation and debridement. Culture results were as follows: *Klebsiella pneumoniae* (2), *Pseudomonas aeruginosa* (2), *Acinetobacter calcoaceticus-baumannii* complex (1), and *Staphylococcus aureus* (1). One subject's cultures were negative and 1 subject had 2 separate species grow during

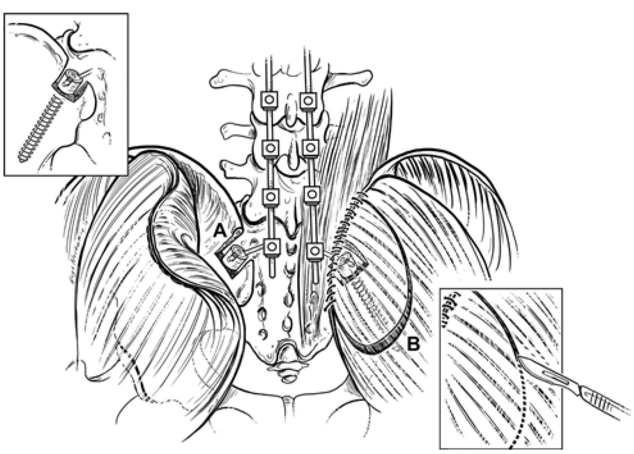

FIGURE 2. Schematic demonstrating: A, Placement of pelvic screw with a 2 cm (depth) cutout at level of posterior superior iliac spine. B, Relaxing fascial/muscular incision over gluteus for soft-tissue advancement and coverage of screw.

TABLE 1. Comparison of Nonstandardized and Plastic Multilayered Groups

	Nonstandardized		Plastic Multilayered		
Variables	**n**	**Mean (± SD)**	**n**	**Mean (± SD)**	***P***
Age (y)	42	14.26 (2.46)	34	13.85 (2.88)	0.507
Fused levels	42	15.17 (2.28)	34	14.76 (3.26)	0.530
Estimated blood loss (mL)	42	894.05 (499.41)	34	998.53 (933.99)	0.559
Packed red blood cells units	42	1.00 (0.96)	34	1.15 (1.52)	0.626
Operating room time (min)	39	403.44 (114.70)	34	450.76 (123.27)	0.094

TABLE 2. Frequency of Primary Diagnoses

Diagnosis	n (%) Nonstandardized (n = 42)	Plastic Multilayered (n = 34)	Total (n = 76)	χ^2 Analysis (*P*)
Cerebral palsy	16 (38.1)	13 (38.2)	29 (38.2)	0.633
Familial dysautonomia	7 (16.7)	2 (5.9)	9 (11.8)	
Prader-Willi syndrome	3 (7.1)	1 (2.9)	4 (5.3)	
Paralytic scoliosis	2 (4.8)	2 (5.9)	4 (5.3)	
Muscular dystrophy	2 (4.8)	2 (5.9)	4 (5.3)	
Other	12 (28.6)	14 (41.2)	26 (34.2)	

Other diagnoses include: osteogenesis imperfecta (1), Rett syndrome (2), Marfan syndrome (3), Mobius syndrome (1), Warkany syndrome (1), arthrogryposis (1), mucolipidosis type IV (1), cleidocranial dysplasia (1), Sturge-Weber syndrome (1), myelomeningocele (2), hydrocephalus (1), infantile fibrosarcoma (1), Morquio syndrome (1), Dandy Walker syndrome (2), panhypopituitarism (2), syringomyelia (2), Russell-Silver syndrome (1), pseudoachondroplasia (1), tuberous sclerosis (1), neurofibromatosis (1).

culture. The specific subject data in all patients with wound complications are shown in Table 4.

DISCUSSION

Postoperative wound complications in patients undergoing posterior spinal fusion are associated with high morbidity and significant cost to patients, families, and providers. Infection can undermine the rate of correction and overall goals of treatment and can have a negative impact on patient satisfaction.[12] Several risk factors for increased infection have been previously identified including primary diagnosis, increased operating room time, and increased need for blood transfusions.[2,18–21] More severe neurological impairment has been identified by several authors as an independent risk factor for infection, possibly related to an increased risk of wound contamination due to incontinence.[14,18,20,21] A primary diagnosis of myelomeningocele portends a worse prognosis for postoperative infection, with rates up to 24%.[2,20,21] The subsequent need for transfusion has also been independently identified as risk factor for infection.[19,22] Master and colleagues performed a retrospective case-control study on neuromuscular patients with a minimum of 2-year follow-up. They determined that there was a bimodal distribution of infections, with early infections occurring at an average of 12.4 days postoperatively and late infections occurring at an average of 2.7 years. They also determined that early infection was associated with an increased rate of pseudarthrosis and increased length of hospitalization.[23] The use of a plastic multilayered wound closure technique for these spinal wounds has not been previously evaluated.

The reconstructive approach to the soft tissue of the back after spinal instrumentation and fusion has 5 primary goals: (1) the obliteration of dead space with vascularized tissue, (2) the creation of a true barrier to separate compartments, (3) the prevention of chronic attenuation/erosion over time with mobilization of tissue for coverage of pressure areas and implant prominence, (4) the recruitment of tissue for areas of relative void after correction, and (5) the elimination of ischemic factors at the skin level to prevent dehiscence. The significance of each factor differs from patient to patient; however, the approach remains consistent for all patients. The approach involves an isolation of components and then a closure in layers to achieve the goals.

We performed a retrospective chart review and determined that the use a plastic multilayered closure technique is associated with a significant decrease in the acute wound complication rate in this patient population. A post hoc power analysis demonstrated that we were adequately powered to evaluate this endpoint. We found a 19% postoperative wound complication rate in our patient population, which is in accordance with other cited studies.[10,12,24,25] The predominant primary diagnosis in our patient population was cerebral palsy, with an incidence of 38.2% (29 of 76). We treated a significant number of patients with familial dysautonomia, which may not represent the experience of the community as a whole as we are a tertiary referral center for patients with that diagnosis. No patients in this study required a removal of implant and all infections that were treated operatively required either 1 or 2 debridements.

Our study has several limitations. First is that it is a retrospective chart review. Limitations in availability and accuracy of data are germane to this study design. The patients were not randomized in a blinded manner and followed prospectively. Such a study would be a significant undertaking and we believe that a retrospective study provides an interesting insight into a method to decrease wound complications in this patient population. Second, we cannot control for the fact that a second surgeon was involved in wound closure. A possible confounder is having a rested surgeon involved in wound closure as opposed to the primary surgical team may have an unseen effect on infection rates, independent of closure type. Further work should be

TABLE 3. Frequency of Wound Complication and Return to Operating Room

	n (%) Nonstandardized (n = 42)	Plastic Multilayered (n = 34)	χ^2 Analysis (*P*)	Odds Ratio
Wound complication	8 (19.0)	0	0.007	10.2
Return to operating room	5 (11.9)	0	0.061	6.2

TABLE 4. Wound Complication Patient Data*

Age (y)	Sex	Diagnosis	Procedure (# Levels)	Return to operating room	POD	Culture
15	M	Paralytic	PSF T2-L5 (16)	Yes, I&D × 1	24	*Staphylococcus aureus*
18	F	Cerebral palsy	PSF T2-Pelvis (18)	No, local wound care	N/A	N/A
9	F	Paralytic	PSF T2-L5 (16)	Yes, I&D × 2	5	Negative
10	M	Cerebral palsy	PSF T2-Pelvis (18)	No, IV antibiotics	N/A	*Pseudomonas aeruginosa*
17	M	Cerebral palsy	PSF T2-Pelvis (18)	Yes, I&D × 1	9	*Klebsiella pneumoniae* *Acinetobacter calcoaceticus-baumannii*
17	F	Syringomelia	PSF T4-L4 (13)	Yes, I&D × 2	5	*P. aeruginosa*
12	F	Cerebral palsy	PSF T2-L5 (16)	No, local wound care	N/A	N/A
14	M	Russell-Silver syndrome	PSF T2-L2 (13)	Yes, I&D × 1	6	*K. pneumoniae*

*All wound complications were in the nonstandardized closure arm of the study.
F indicates female; I&D, irrigation and debridement; M, male; POD, postoperative day when irrigation and debridement occurred; PSF, posterior spinal fusion.

considered to have the plastic multilayered closure performed by the primary team to further delineate the effect of this variable. Furthermore, all closures were performed by a single plastic surgeon with specific interest and training in this area. Our results may be considered less generalizable given this. Lastly, we are not certain due to variability of closure technique how the nonstandardized wounds were closed. However, while this may seem a detraction to our study, this is similar to many institutions, where closure is far from standardized in terms of personnel and technique.

In conclusion, our data show that the use of a plastic multilayered closure technique by a plastic surgeon for posterior spinal fusion treatment of nonidiopathic scoliosis is associated with a significantly lower rate of postoperative wound complications. It is also likely associated with a lower incidence in unanticipated returns to the operating room for irrigation and debridement, although this finding did not reach statistical significance. We believe this association may be causative and that this manner of wound closure should be considered in this patient population in an effort to lower the substantial complication rate associated with this diagnosis and procedure. Future prospective studies would better define this association and potentially identify other operative techniques to reduce the complication rate in patients with idiopathic scoliosis, as well.

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