COVER: A Curriculum in the Management of Soft Tissue Injury and Infection for Junior Surgery Residents

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ABSTRACT

Background While wound management is a common task for practicing surgeons, there is a paucity of dedicated education on soft tissue management during residency training.

Objective The COVER (Causes of soft tissue injury, Obstacles to closure, Vacuums and stitches, Epithelialization, Rationale for wound care) curriculum was developed to engage junior surgery residents in the management of soft tissue injury and infection.

Methods Junior surgery residents participated in the COVER lab during academic years 2018–2020. Residents applied appropriate surgical management and wound care to cadaveric models of soft tissue injury and infection. Assessments included a pre-/post-curriculum and pre-/post-lab multiple choice questionnaire and survey.

Results All eligible residents (n = 45, 27) participated in the COVER lab for both academic years. Postgraduate year (PGY)-1s, PGY-2s, and PGY-3s showed improvement in wound management knowledge with an average increase in score of 17%, 8%, and 18%, respectively. They also showed a change in their self-reported perceived ability to achieve primary soft tissue closure with confidence levels 22%, 20%, and 16%, respectively. This was again seen in perceived ability to manage soft tissue injuries and infections (28%, 28%, and 23%, respectively). There was a significant increase in performing new wound management skills (PGY-1 mean 51.3%, PGY-2 33.5%, PGY-3 20%; ANOVA, $P = .0001$).

Conclusions The COVER curriculum provides a systematic approach to soft tissue injury and infection. Residents showed a significant increase in both soft tissue knowledge as well as confidence in ability to perform wound management.

Introduction

Soft tissue infection and injury present significant challenges to both patient and provider. The skin is the body's largest organ; thus, soft tissue disease represents a manifestation of systemic health, requiring proper diagnosis, resuscitation, management, and support. While the enormity of the burden of soft tissue disease may be evident to a patient, surgeons may not be aware of the broad range of approaches to facilitate healing.

Self-guided education in wound care is difficult due to lack of consensus in the literature; guidelines are often based on small studies and expert opinions.[1–3] Additionally, the rapid progression of wound care technology and studies driven by industry makes discerning the most effective product for a given wound challenging.[4] Wound care education has been identified as a gap in many residencies, including dermatology, internal medicine, and family medicine.[1,5,6] While a robust body of literature exists on nurse education in wound care, no literature exists on wound care curricula in surgical education.[7] Although wound care is multidisciplinary, surgeons play a vital role in the treatment of chronic wounds.[8]

To overcome these deficits in resident education, we developed the COVER (Causes of soft tissue injury, Obstacles to closure, Vacuums and stitches, Epithelialization, Rationale for wound care) curriculum in 2018 to engage junior surgery residents in the management of soft tissue injury and infection. Additionally, this is a novel curriculum that targets an area of surgical practice and training that accounts for significant morbidity in patients, including both physically and psychosocially.[9] The overall goal of the COVER course is to equip surgical residents with the training to identify and treat soft tissue injury and infection, ideally helping to reduce the morbidity and mortality associated with these conditions in patients. This article will not only describe an assessment of the

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Editor's Note: The online version of this article contains a list of supplies needed for COVER lab, proctor verbal qualitative assessment form, 2018 post-lab questionnaire, and 2018 pre-curriculum survey.

curriculum, but also the curriculum itself for adaptation by other training programs.

Objectives
The COVER (Causes of soft tissue injury, Obstacles to closure, Vacuums and stitches, Epithelialization, Rationale for wound care) curriculum was developed to engage junior surgery residents in the management of soft tissue injury and infection.

Findings
Postgraduate year (PGY)-1, PGY-2, and PGY-3 residents showed improvement in wound management knowledge with an average increase in score of 17%, 8%, and 18%, respectively, and performed new wound management skills (PGY-1 mean 51.3%, PGY-2 33.5%, PGY-3 20%; ANOVA, $P = .0001$).

Limitations
These include the limited knowledge evaluations, small sample size, self-reported results, and single institution study.

Bottom line
The COVER curriculum provides a systematic approach to soft tissue injury and infection.

Methods

COVER Curriculum

The goal of the COVER curriculum was to create a holistic approach to teaching junior residents about the management of soft tissue injury and infection through didactic teaching as well as a hands-on lab (TABLE 1). Objectives were designed to teach all surgical residents the diagnosis and management of injuries through didactics and a cadaver simulation lab (BOX 1). Didactic sessions were taught during the weekly educational conference attended by all residents, followed by the hands-on lab session, which was limited to junior residents, synchronously. The COVER curriculum has now been taught in the beginning (July–August) of 2 academic years (2018–2019 and 2019–2020). Resources needed for the curriculum include three 1-hour didactic lectures given by attending physician experts in their field as well as a 3-hour simulation lab using a cadaveric model also proctored by 2 surgeon faculty members.

COVER Curriculum Didactics

Over the 3-week course, junior (PGY-1–3) and senior (PGY-4–5) residents attended 3 didactic lectures for 1 hour each, following the Surgical Council on Resident Education (SCORE) curriculum.[10] Each was taught by an expert in their topic, which included basics in tissue anatomy, common injuries and infections, antibiotic therapies and microbial resistance, and wound care and treatment adjuncts. Additionally, one of the didactic lectures included multiple challenging case presentations of patients the residents had seen and treated over the past year. These patient case scenarios followed the 6 injury types outlined in the curriculum objectives that were then to be taught in the hands-on lab (TABLE 2). During this session, emphasis was placed on discussing an approach to these injuries that fully incorporates a patient's systemic health to both treat and prevent further tissue injury.

COVER Curriculum Lab

Over a 3-hour time period, junior residents (PGY-1 to PGY-3) participated in the COVER lab based on defined objectives (BOX 2). Cadaver models were used to demonstrate soft tissue injury and infection, including an open abdomen, an enteroatmospheric fistula, extremity fasciotomies, a partial thickness skin defect, and deep soft tissue wounds. In the second year, due to cost constraints, the lab was limited to PGY-1 and PGY-2 residents, and only cadaveric lower extremities were used to model fasciotomies, a partial thickness skin defect, deep soft tissue wounds, and a toe amputation. The total cost of the lab in the first year with full cadavers was $30,456; by limiting the number of participants and using only cadaveric limbs the cost in the second year was reduced to $22,350. Faculty opened the lab with a brief preoperative discussion of the lab objectives. In teams of 3, residents completed 6 scenarios based on different anatomical areas of injury. They first created the injuries and then worked to apply appropriate surgical management and wound care, including definitive closure, partial closure, open management with topical dressings, and negative pressure wound therapy (TABLE 2; more information provided as online supplementary data). The scenarios represented real patients who had been treated at Washington University in St. Louis. At least 2 faculty proctors were present to provide verbal assessment and guidance on functionality and durability of the techniques used (provided as online supplementary data). In order to minimize inter-educator variability, one of the proctors was present for each lab session.

Method of Analysis

We examined pre- and post-lab questionnaires of wound management knowledge (assessed by multiple-choice questions), confidence levels in management techniques (rated on a 1–5 scale), and a survey of technical skills completed for the first time assessed by multiple-choice questions (representative example of post-lab survey provided as online supplementary data).

Results were pooled across the 2018 and 2019 academic years except in the assessment of procedures that were only performed in the first year of the course.

TABLE 1
Description of COVER Curriculum Components by Bloom's Taxonomy[11]

Activity	Overall Objective With Cognitive Process Dimensions	Knowledge Dimension	Length	Instructor: Participants
Didactic lectures	▪ Remember, understand, and apply formal education on soft tissue injury and infection prevention and management, following SCORE curriculum guidelines Lectures 1 & 2: ▪ Recognize soft tissue injury and infection ▪ Recall ideal antibiotics therapy and the role of super bugs in management ▪ Summarize wound care and adjuncts to wound care ▪ Recall helpful tissue anatomy	Factual	1 hour each	Attending: all residents
	Lecture 3: ▪ Apply formal knowledge to patient case scenarios	Conceptual		
COVER lab	▪ Analyze soft tissue injuries in a simulated setting ▪ Apply management techniques	Procedural	3 hours	1–2 attendings overall; groups of 2–3 junior residents (PGY-1–3s)

Additionally, we examined pre- and post-surveys of all surgical residents who participated in the didactic COVER curriculum in its inaugural year (both surveys had identical content questions provided as online supplementary data). A paired *t* test was used to test for differences in repeated measures. One-way analysis of variance (ANOVA) with Dunnett's multiple comparison test was used to test for difference between multiple normally distributed. Statistical analysis was performed using GraphPad Prism version 7.02 for Windows (GraphPad Software, La Jolla, CA). This study was approved by the Washington University in St. Louis Institutional Review Board.

Results

In 2018, all 45 PGY-1 to PGY-3 residents from general surgery, vascular, plastics, and urology participated in the lab. The PGY distribution was as follows: 45% PGY-1s (n = 20), 33% PGY-2s (n = 15), and 22% PGY-3s (n = 10). In 2019, all 27 PGY-1 and PGY-2 residents participated; 63% PGY-1s (n = 17) and 37% PGY-2s (n = 10). All general surgery residents (PGY-1–PGY-5) participated in the COVER didactics, with a total response rate of 72% for the 2018 pre- and post-surveys and distribution as follows: 23% PGY-1s (n = 10); 35% PGY-2s (n = 15, including lab residents); 21% PGY-3s (n = 9); 14% PGY-4s (n = 6); and 7% PGY-5s (n = 3).

Impact of COVER Didactics

Residents reported to have completed an average of 2.35 hours of education of soft tissue injury and infection prior to the COVER course (PGY-1: 0; PGY-2: 3; PGY-3: 0.72; PGY-4: 5.33; PGY-5: 3.33). Confidence in the ability to diagnose and manage soft tissue injuries increased across all clinical years

TABLE 2
Example of a COVER Lab Scenario

Case Description and Imaging	Injuries to Make and Management
▪ Adult M who presents as a heroin overdose ▪ Examination: Tense left lower extremity, tachycardic ▪ Imaging: CT of left lower extremity shows popliteal arterial thrombus ▪ Interim treatment: Undergoes left popliteal artery thrombectomy ▪ Objective: ▫ Create4-compartment fasciotomy ▫ Managementof 4-compartment fasciotomy incisions	▪ Make 20 cm fasciotomy incisions ▫ Medial:1 cm (1 finger) posterior to the tibia toward the medial malleolus ▫ Lateral:1 cm (1 finger) anterior to the fibula toward the lateral malleolus ▪ Provide temporary closure with nonadherent layer ▪ Provide temporary closure with negative pressure wound therapy ▪ Provide definitive closure with topical negative pressure

BOX 1 COVER Curriculum Objectives by Injury Type

Crush Injury

- Describe the mechanism of injury
- Identify the grade of injury
- Recognize clinical pitfalls
- Determine the role of radiography and labs
- Apply surgical management
  - Stabilization of fractures, decontamination, tissue debridement, tissue resuscitation, tissue closure, secondary healing
- Incorporate patient care into wound management
  - Pain control, nutrition, antimicrobials, fluid management, organ support, anesthesia exposure, rehabilitation

Necrotizing Injection

- Describe the mechanism of injury
- Identify the grade of injury
- Recognize clinical pitfalls
- Determine the role of radiography and labs
- Apply surgical management
  - Tissue debridement, tissue resuscitation, tissue closure, secondary healing
- Incorporate patient care into wound management
  - Pain control, nutrition, antimicrobials, fluid management, organ support, anesthesia exposure, rehabilitation

Deep Tissue Pressure Injury

- Describe the mechanism of injury
- Identify the grade of injury
- Recognize clinical pitfalls
- Determine the role of radiography and labs
- Apply surgical management
  - Tissue debridement, tissue resuscitation, tissue closure, offloading, secondary healing
- Incorporate patient care into wound management
  - Pain control, nutrition, antimicrobials, fluid management, organ support, anesthesia exposure, rehabilitation

Surgical Incisions

- Classify wound
  - Contamination, edema, tension, systemic risk factors
- Determine ideal type of closure
  - Suture, drains, adjuncts
- Recognize clinical pitfalls

Open Abdomen/Fistula[a]

- Identify the indications for temporary abdominal closure
  - Damage control, compartment syndrome
- Determine the ideal type of temporary closure
  - Negative pressure, synthetic closure, partial closure
- Recognize clinical pitfalls
- Determine the role of radiology and labs
- Apply surgical management
  - Maintenance of domain, tissue resuscitation, tissue closure, control of tension, primary closure, secondary healing
- Incorporate patient care into wound management
  - Intraabdominal hypertension, pain control, nutrition, antimicrobials, fluid management, organ support, anesthesia exposure, rehabilitation

Skin Disorders

- Categorize differential diagnosis
  - Cellulitis, DVT/venous insufficiency, hidradenitis, calciphylaxis, vasculitis, ecthyma gangrenosum, squamous cell carcinoma
- Compare and contrast possible management techniques
  - Biopsy, exploration, medical management, wound care
- Recognize clinical pitfalls
- Determine the role of radiology and labs
- Apply surgical management
  - Indications for resection, primary closure, secondary healing
- Incorporate patient care into wound management
  - Pain control, nutrition, antimicrobials, fluid management, organ support, anesthesia exposure, rehabilitation

with completion of the curriculum; however, the most drastic increase in confidence gained was in the intern class (PGY-1: 67% increase; PGY-2: 29% increase; PGY-3: 22% increase; PGY-4: 6.3% increase; PGY-5: 7.1% increase). Residents throughout all clinical years showed improvement in their knowledge of soft tissue injury management on the paired pre- and post-course assessments. Significant improvement was seen in PGY-2 and PGY-3 residents, with an average improvement in score of 11% ($P = .027$) and 25% ($P = .007$), respectively (FIGURE 1). PGY-1, PGY-4, and PGY-5 residents also showed a positive increase in knowledge gained.

Impact of COVER Lab

PGY-1, PGY-2, and PGY-3 residents showed improvement in wound management knowledge by pre- and post-lab assessments with an average increase in score of 17% ($P = .0002$), 8% ($P = .032$), and 18% ($P = .001$), respectively. PGY-1, PGY-2, and PGY-3 residents showed a significant change in their perceived ability to achieve primary soft tissue closure with confidence levels increasing by 22%, 20%, and 16%,

BOX 2 COVER Lab Objectives

Overall goal: To complete the COVER lab, teams of 3 must create and appropriately manage each injury in each of the 6 anatomic areas.

1 – Lower leg: Lower extremity 4 compartment fasciotomy
- Create 4 compartment lower leg fasciotomies
- Provide fasciotomy temporary closure
- Provide fasciotomy definitive closure

2 – Foot: Great toe amputation
- Amputate great toe
- Provide amputation temporary closure
- Provide amputation definitive closure

3 – Upper leg: Femoral cutdown and partial thickness injury
- Create femoral cutdown and partial thickness injury
- Complete groin wound debridement and temporary closure
- Provide definitive groin wound closure
- Provide partial thickness coverage

4 – Abdomen: Laparotomy
- Create exploratory laparotomy incision
- Provide temporary abdominal closure
- Provide definitive abdominal closure
- Manage enteroatmospheric fistula

5 – Chest: Sternotomy
- Create sternotomy incision
- Provide sternotomy temporary closure
- Provide sternotomy definitive closure

respectively ($P < .0001$ for each; FIGURE 2). This was again seen in assessing their improvement in perceived ability to manage soft tissue injuries and infections (28%, 28%, and 23%, respectively; $P < .0001$, $P < .0001$, and $P = .0003$; FIGURE 2). Additionally, there was a significant increase with more junior residents performing new wound management skills never completed before (PGY-1 mean percentage 51.3%, PGY-2 mean 33.5%, PGY-3 mean 20%; ANOVA; $P = .0001$; FIGURE 3). In the first year of the course, the most common new skills performed by participating PGY-1s to PGY-3s were control of an enteroatmospheric fistula with negative pressure therapy (58% of residents [26 of 45]), creation of a 4 compartment lower leg fasciotomy (56%, 25 of 45), and placement of a negative pressure wound therapy with instillation (44%, 20 of 45). In the second year of the course, the most common new skills for participating PGY-1s and

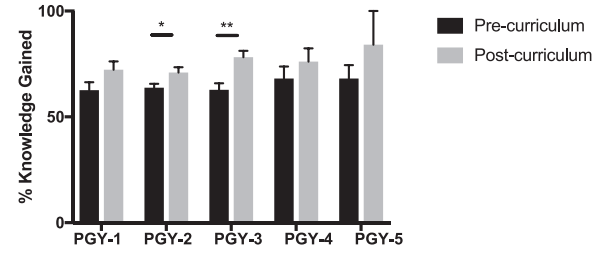

FIGURE 1
Mean Percentage of Knowledge Gained From COVER Curriculum

Note: Residents throughout all clinical years showed improvement in their knowledge of soft tissue injury management after the COVER curriculum. Significant improvement was seen in the PGY-2 and PGY-3 residents, with an average improvement in knowledge score of 11% (*$P < .027$) and 25% (**$P = .007$), respectively.

PGY-2s were 4 compartment lower leg fasciotomy (89%, 24 of 27), great toe amputation (81%, 22 of 27), and use of negative pressure wound therapy on an open wound (81%, 22 of 27). The higher percentages of skills being performed for the first time in the second year of the course is likely due to the change in participant composition from PGY-1–PGY-3 to PGY-1 and PGY-2 only. Across both years, mean new procedures performed decreased by PGY, with PGY-1s performing 6.4 procedures for the first time, PGY-2s performing 4.3 new procedures, and PGY-3s 2.8 new procedures.

Discussion

The COVER curriculum was effective in increasing surgical residents' knowledge in managing simulated soft tissue injury and infection. While all PGY groups showed an increase in knowledge scores, PGY-4s and PGY-5s had the least improvement, which is expected given that they have had more years of clinical experience. The junior residents benefited from both the curriculum and the lab experience. They showed

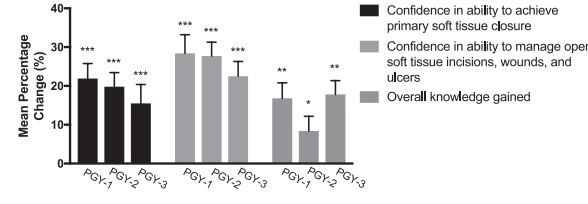

FIGURE 2
Mean Percentage Change in Pre- and Post-Lab Confidence and General Knowledge

Note: PGY-1s, PGY-2s, and PGY-3s showed a significant change in their perceived ability to achieve primary soft tissue closure, with confidence levels increasing by 22%, 20%, and 16%, respectively (***$P < .0001$). PGY-1s, PGY-2s, and PGY-3s showed improvement in perceived ability to manage soft tissue injuries and infections (28%, 28%, and 23%, respectively; ***$P < .0001$). PGY-1s, PGY-2s, and PGY-3s increase in general knowledge increasing by 17%, 8%, and 18%, respectively (**$P < .005$, *$P < .05$).

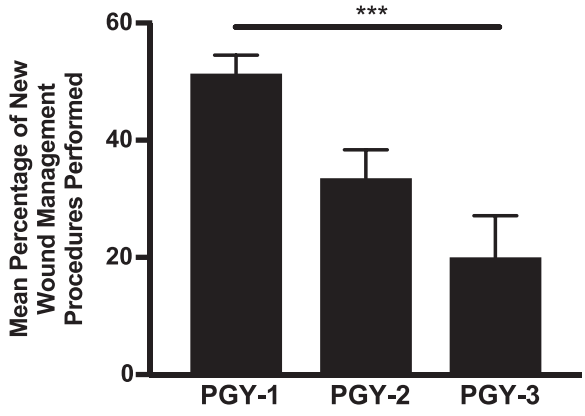

FIGURE 3
Mean Percentage of New Wound Management Procedures Performed by PGY

Note: PGY-1, PGY-2, and PGY-3 with 51%, 34%, and 20% increases in wound procedures performed (ANOVA ***$P < .0001$).

significant increases in knowledge as well as technical skills gained.

With increasing budget constraints and limited work hours resulting in fewer patient contacts, traditional surgical skills acquisition through the apprenticeship is threatened.[12,13] Prior studies have shown a correlation with frequency of operations performed and patient outcomes.[14] Wound care is one of the basic tenants of general surgery. Despite early training in surgical clerkships, soft tissue injury and infection is an incredibly broad topic requiring intensive study.[15] Therefore, a robust curriculum with simulation training is necessary for both exposure and acquisition of managing this disease.[16]

Cadaver-based simulation models have been shown to improve surgical residents' confidence and exposure to new procedures[8,17]; however, no prior studies have looked at cadaver simulation for teaching wound care techniques. The COVER curriculum goes beyond typical cadaver-based simulation and didactics through the use of case-based training, which has been identified as a mechanism to train higher-level competencies, such as complex decision-making abilities in addition to surgical skills.[6] Previous efforts to improve wound care training among internal medicine residents have focused on didactic sessions and inpatient exposure to acute wounds and have resulted in residents changing their practice.[1,18] For surgical residents, both didactic knowledge and technical skills related to wound management are necessary to provide adequate care to patients with soft tissue injury. The nursing literature revealed that nurses with dedicated didactic training in wound care have improved rates of wound care knowledge, while years in practice alone do not significantly affect wound care knowledge.[19] Within our resident cohort, more years of practice corresponded to greater wound care knowledge and less improvement from pre- to post-test likely related to the increased exposure to wound care over the course of surgical residency. The COVER curriculum fosters an environment in which higher level of competencies can be trained, paralleling the Accreditation Council for Graduate Medical Education (ACGME) Surgical Milestones.[20]

Our goal was not only to establish this novel curriculum to increase resident exposure to wound care, but also to target an area of surgical practice and training that has a significant morbidity associated with it for its patient as well as the health care system. Chronic wounds are a silent epidemic, with an estimated 6.5 million patients suffering from them in the United States.[21,22] It has been shown that open wounds lead to loss of independence, depression, and decreased mobility in patients with wounds left to heal by secondary intention.[9] Additionally, chronic wound care also poses a significant financial burden to the health care system, with the United States tallying a total of $25 billion annually in chronic wound care expenditures.[23,24] With the growing prevalence of cases, a curriculum to educate rising clinicians is both timely and necessary.

In future iterations of this lab, we hope to develop more stringent tools to evaluate resident performance in completing each case, with emphasis on functionality and durability of the techniques utilized. Limitations of this study include the evaluation pre- and post-assessments including only multiple-choice questions, which may not fully illustrate a resident's breadth of knowledge. Additional limitations include small sample size, self-reported results, and single institution study. Although proctors were involved in verbal, hands-on corrections during the lab, these qualitative comments need to be recorded as well as a formal assessment. Furthermore, with the major role of nursing in wound care, we hope to continue to develop a more robust, multidisciplinary curriculum as well as more thorough, externally validated assessments.

Conclusions

The COVER curriculum provides a systematic approach to soft tissue injury and infection. Junior residents showed a significant increase in both soft tissue knowledge as well as confidence levels in ability to perform wound management skills. The more junior the resident, the more new skills were performed during the lab.

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