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Outcomes of rural trauma patients who undergo damage control laparotomy

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ABSTRACT

Background: The majority of motor vehicle crashes occur in a rural setting and those patients have double the mortality of their urban counterparts. These trauma patients are at times stabilized at rural hospitals before transfer to a Level 1 trauma center. The purpose of this study was to determine the outcomes of rural damage control laparotomy used as a means of pre-transfer stabilization.
Methods: A nearly 7-year retrospective review was conducted of rural trauma patients who had laparotomies before or after transfer to Level 1 center. They were grouped into three categories: damage control laparotomy at rural hospital, patients unstable during transfer or stable during transfer with subsequent laparotomy.
Results: Forty-seven patients met study criteria. Overall mortality was significantly different between patients who had damage control laparotomy at a rural hospital (14.3%), were unstable transfer patients (75.0%), and stable transfer patients (3.3%; $P < 0.001$).
Conclusion: Rural damage control laparotomy may be used as a means of stabilization prior to transfer to a Level 1 center, and in appropriate patients may be life-saving.

Introduction

Rural populations have nearly twice the trauma mortality as their urban counterparts. The National Highway Traffic Safety Administration estimates that 61% of all fatal motor vehicle crashes occur in the rural setting.[1] Additionally, the highest mortality of motor vehicle crashes occurs in the lowest populated counties in the United States with lowest per capita income.[2] Since most rural hospitals are ill-equipped to care for complex trauma patients' long-term needs, they transfer them to regional trauma centers. It is well-established that since the creation of regional trauma centers, traumatic mortality has decreased significantly. Rural patients are routinely transferred to Level 1 trauma centers that have more resources and experienced trauma staff.[3] Other factors such as surgeon training and confidence may also influence the decision to transfer patients to urban centers prior to attempting operative stabilization, often referred to as damage control laparotomy (DCL). However, there are times when rural surgeons can perform DCL to stabilize trauma patients before transfer, and DCL in the rural setting might be life-saving.

There is an inherent difficulty when evaluating the risks and benefits of DCL. Patients who require DCL are often seriously injured with significant metabolic and hemodynamic derangements. Stone et al.[4] demonstrated that most patients who did not undergo DCL and packing had ongoing coagulopathy (12 out of 14 patients) and eventually succumbed to hemorrhage with a subsequent mortality of 93%. Of those that underwent DCL and packing, coagulopathy was corrected in the majority of patients (14 of the 17), with only one patient succumbing to hemorrhage. Further, a study by Aoki et al.[5] demonstrated that patients who underwent DCL had clinically significant disturbances in their pH and PTT; inability of the clinician to correct these disturbances lead to an increase in the odds of mortality (4.43 for every 0.1 drop in pH and 9.4 for those with a PTT > 80 s).

Several other studies have also evaluated the overall mortality of DCL patients. Mortality in these studies is quite variable, ranging from 10% to 73%.[6–8] This variation is largely due to patient factors, but also to the evolution of DCL. As surgeons become more

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comfortable with DCL, patient selection and survival improves. While studies have evaluated DCL outcomes,[6,9] only one has specifically targeted DCL in the rural population. Weinberg et al.[10] examined the outcomes of trauma patients who underwent DCL at a rural hospital before transfer to a higher tier facility. They found that these patients had reasonable overall outcome with 82% overall survival.

We therefore sought to evaluate DCL in the rural setting. The purpose of this study was to evaluate the outcomes of rural trauma patients who had DCL at a rural facility versus those who had exploratory laparotomies at a Level 1 Trauma Center.

Methods

Patient selection and treatment groupings

The trauma registry at our American College of Surgeons Committee on Trauma (ACSCOT)-verified Level 1 trauma center was used to first identify all trauma patients aged 18 years or older with abdominal injuries who were transferred to our facility from a rural facility between January 1, 2010 to September 30, 2016. For the purposes of this study, any ACSCOT Level II-IV hospital or critical access hospital was considered rural. Only patients who had exploratory laparotomies, either at the rural facility or our facility, were included in this study.

Patients were then stratified into the following groups: (1) those who had a damage control laparotomy performed at a rural hospital (DCL), (2) those who were considered unstable at the rural hospital and were immediately transferred from the rural hospital and had exploratory laparotomy within 2 h of arrival from the outside hospital (ELU), and (3) those considered stable at the rural hospital and had exploratory laparotomy between 2 and 12 h of arrival from the outside hospital (ELS). Damage control laparotomy was defined as a laparotomy without fascial closure.

Data collection

Following patient identification, a retrospective review was conducted of patient medical records within the trauma registry as well as the patient chart for data collection. Data collected included demographics (age, gender, race), mechanism of injury, injury severity (Glasgow Coma Scale [GCS] score, injury severity score [ISS]), systolic blood pressure, blood products administered, injury details, and hospitalization outcomes (ICU admission and length of stay, mechanical ventilation use, hospital length of stay, and mortality).

Statistical analysis

For univariate analyses, comparisons of continuous and categorical data were conducted using t-tests and Chi-square analysis, respectively. For continuous variables that were not normally distributed, a Kruskal-Wallis test was used to compare distributions. When significant differences were observed between the three comparison groups, post hoc analyses were used for pairwise comparisons. All statistical tests were two-sided and analyses were considered significant when the resultant P value was ≤ 0.05. Post hoc statistical tests were adjusted using a Bonferroni correction to account for multiple comparisons. All analyses were conducted using SPSS release 19.0 (IBM Corp., Armonk, New York).

This study was reviewed and approved for implementation by the Institutional Review Board of Via Christi Hospitals Wichita, Inc.

Results

Our facility is located in south central Kansas in Wichita, Kansas, which is the most populated city in the state. The State of Kansas has three level I and two level II trauma centers concentrated in a small geographic area. By contrast, the rest of the state is largely rural in nature. Level III and level IV facilities exist throughout the state with community access hospitals (CAH) to help fill gaps in coverage. Patients in this study were transferred from a variety of facilities (CAH, level III, level IV) across the state and are summarized in Fig. 1.

Of the 187 patients transferred from a rural facility during the study timeframe, 45 (24.1%) met criteria for inclusion into the study. Those 45 were then divided into three study groups: (1) damage control laparotomy at rural hospital (DCL), (2) stable patients with laparotomy at level 1 trauma center (ELS), and (3) unstable patients with laparotomy at a level 1 trauma center (ELU).

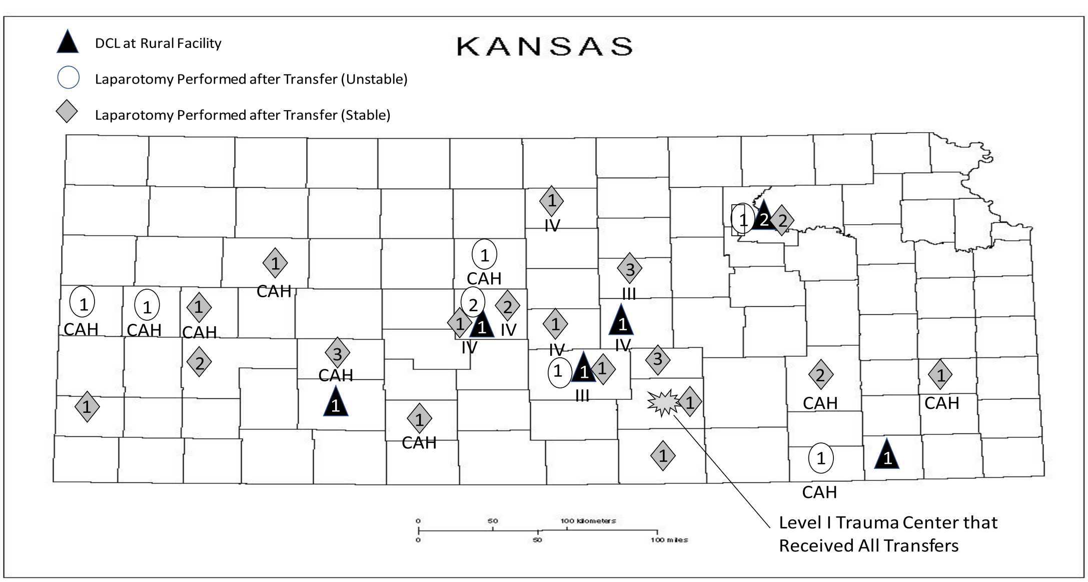

Fig. 1. Map of the state of Kansas depicting the locations of the transferring facilities with number of patients transferred and facility designations. CAH = critical access hospital.

Table 1
Demographic summary of patients that underwent a laparotomy before or after transfer for traumatic injury.

Parameter[a]	Treatment Group			P value
	Damage Control Laparotomy at Rural Facility	In Stable Condition with Laparotomy After Transfer	Unstable Condition with Laparotomy After Transfer	
Number (%)	7 (15.6%)	30 (66.7%)	8 (17.8%)	–
Age (years)	26.0 ± 5.9[a]	39.1 ± 17.8[a,b]	51.5 ± 24.6[b]	0.036
Male sex	6 (85.7%)	21 (70.0%)	5 (62.5%)	0.596
Race				0.315
White	6 (85.7%)	22 (73.3%)	8 (100%)	
Black	1 (14.3%)	2 (6.7%)	0 (0%)	
Other	0 (0%)	6 (20.0%)	0 (0%)	

Values within rows with different superscript letters are different at the P<0.05 level.
[a] Presented as number (%) or mean ± standard deviation.

The DCL, ELS, and ELU groups had 7, 30 and 8 patients, respectively (Table 1). The majority of the patients were male and white in all 3 groups. Patients in the DCL group had a mean age of 26 years; while patients who were transferred (ELS and ELU) had a mean age of 39.1 years and 51.5 years, respectively.

Patients who had a DCL were more likely to have penetrating trauma (57.1%) as compared to ELS (16.7%) and ELU patients (12.5%, $P = 0.052$; Table 2). Regarding severity of injury, ELU patients had more than double the ISS of the DCL and ELS groups ($P = 0.005$). A comparison of abbreviated injury severity (AIS) scores does not indicate that the difference in ISS was driven by a difference in severity to any particular anatomic region. The difference is most likely due to individuals in the ELU group sustaining injuries in multiple anatomic regions. The initial SBP of the ELU patients was significantly lower (68.9 mmHg) as compared to the DCL and ELS groups, who had similar mean initial SBP in the 110s. Glasgow Coma Scale score was significantly different between groups; however, this data is not clinically relevant as most of the patients in DCL group and those who were unstable during transport were intubated and sedated prior to arrival. Therefore, GCS was artificially lowered in those groups.

All patients had abdominal injuries necessitating exploratory laparotomy. The majority of patients in the ELS group had a small or large bowel injury, with a few suffering from splenic and renal lacerations. The one ELS patient that expired suffered a significant thoracic crush injury, was stable at the rural hospital with blood pressure of 94/73 mmHg at rural transfer, but upon admission to our trauma center had a positive FAST exam, was acidotic and coagulopathic and had fixed and dilated pupils. He was taken emergently to the operating room where he was found to have significant bleeding from the mesentery of the colon.

The patients in the other two groups (DCL and ELU) had more severe injuries, with most of these patients suffering major vascular injuries. Of 8 patients in the ELU group, patient one was a bicyclist hit by a car that had a basilar skull fracture and splenic laceration; patient two had a grade 4 liver laceration; patient three, an ejected passenger of a MVC, had a retroperitoneal hematoma, liver lacerations, and superior mesenteric vein transection; patient four, ejected from an MVC, had liver lacerations, renal hilum disruption, and retroperitoneal hematoma; patient five had a grade 5 splenic injury and a diaphragm laceration; patient six, a motorcyclist involved in an MVC, had a grade 3 splenic laceration, traumatic brain injury and multiple orthopedic injuries; patient seven, a motorcycle passenger involved in an MVC, had complete splenic avulsion; and patient eight was ejected from his motor vehicle and had a distal aortic laceration. Patients one, three, four, six, seven and eight died, with patients three, four, seven and eight all having suffered known major vascular injuries.

DCL patients suffered similar injuries. Of the 7 DCL patients, patient one sustained a grade 5 liver injury; patient two had a 25% circumference distal aorta laceration; patient three had an inferior vena caval laceration and a superior mesenteric artery laceration; patient four had a negative exploratory laparotomy; patient five had a retroperitoneal hematoma; patient six had iliac artery and

Table 2
Injury severity of patients that underwent a laparotomy before or after transfer for traumatic injury.

Parameter[a]	Treatment Groups			P value
	Damage Control Laparotomy at Rural Facility	In Stable Condition with Laparotomy After Transfer	Unstable Condition with Laparotomy After Transfer	
Number (%)	7 (15.6%)	30 (66.7%)	8 (17.8%)	–
Mechanism				0.052
Blunt	3 (42.9%)[a]	25 (83.3%)[a]	7 (87.5%)[a]	
Penetrating	4 (57.1%)[a]	5 (16.7%)[a]	1 (12.5%)[a]	
ISS	19 (9–30.3)[a]	17.0 (10–25.0)[a]	41.5 (33–48.3)[b]	0.005
AIS Head	3 (3–3)	2 (2–3.5)	4.5 (3.3–5)	0.142
AIS Face	2 (2–2)	1.5 (1-n/a)	1.5 (1-n/a)	0.535
AIS Chest	3 (3–3)	3 (2–3)	3 (2–4)	0.687
AIS Abdomen	4.5 (3.3–5)	4 (3–4)	3.5 (2–5)	0.509
AIS Extremity	3 (2-n/a)	4 (3–4)	4 (2–5)	0.807
AIS External	1.5 (1–5)	1 (1–2)	1 (1–2.8)	0.609
GCS score	3 (3–13)[a]	15 (14–15)[b]	3 (3-3)[a]	<0.001
SBP (mmHg)	115.5 ± 60.9[a,b]	111.9 ± 22.4[a]	68.9 ± 62.6[b]	0.073

ISS = injury severity score, GCS = Glasgow Coma Scale, SBP = systolic blood pressure.
Values within rows with different superscript letters are different at the $P \leq 0.05$ level.
[a] Presented as number (%), median (IQR), or mean ± standard deviation.

Table 3
Blood product utilization for patients that underwent a laparotomy before or after transfer for traumatic injury.[b]

Parameter[a]	Treatment Group			P value
	Damage Control Laparotomy at Rural Facility	In Stable Condition with Laparotomy After Transfer	Unstable Condition with Laparotomy After Transfer	
Number (%)	7 (15.6%)	30 (66.7%)	8 (17.8%)	–
FFP (units)	8.3 ± 0.6 (3)	4.7 ± 2.4 (9)	6.7 ± 7.7 (3)	0.482
pRBC (units)	9.8 ± 6.7 (4)	6.8 ± 3.6 (12)	11.0 ± 6.6 (6)	0.242
Platelets (units)	1.6 ± 0.5 (5)	1.4 ± 0.5 (7)	2.2 ± 1.6 (5)	0.419

FFP = fresh frozen plasma, pRBC = packed red blood cells.
[a] Presented as number (%) or mean ± standard deviation (n).
[b] Only 3 patients received cryoprecipitate. One patient received one unit (group 3), another patient received two units (group 2), and a third patient received 3 units (group 1).

vein lacerations; and patient seven had a grade 5 splenic injury. Patient two died from the DCL group. The one patient in the DCL group that expired (patient 2, 23 years of age) suffered stab wounds to the right face, scalp, right neck and anterior abdomen. He had a large retroperitoneal hematoma that the rural surgeon was unwilling to explore, so was packed and transferred. Upon admission to our trauma center he was pulseless, with fixed and dilated pupils and mottling throughout his body.

Trauma patients requiring laparotomy require significant resuscitation; therefore, we evaluated the blood products used. Damage control laparotomy and ELU patients had nearly double the amount of blood product utilized during their resuscitation versus ELS patients. While there was a difference in the average volume of blood products transfused, this did not reach statistical significance (Table 3).

Hospital outcomes were also evaluated (Table 4). No significant difference between groups was discovered in regards to ICU admission, ICU days, mechanical ventilation use and mechanical ventilation days. A statistically significant difference was noted in hospital length of stay and mortality. Only one of 7 patients in the DCL group died, unlike the ELU group where 75% of those patients expired. Most of the patients who expired in the ELU group died very early in their hospital stay, thereby shortening the average HLOS. Specific causes of death with those subject's injuries are shown in Table 5.

Upon evaluation of ultimate discharge locations, differences were noted between groups (Table 6). As mentioned, 75% of patients in the ELU died, but 1 was discharged to a mental health facility and 1 to a specialty hospital. Discharge destination for the DCL and ELS groups were similar, with approximately 60% being discharged to home. A minority of patients were discharged to other institutions, such as skilled nursing or rehabilitation centers.

Comments

Damage control laparotomy is not a new concept. Stone et al.[4] first popularized the idea in the 1980's as a means for resuscitation and correction of coagulopathy before definitive repair of traumatic injuries. Selection of the appropriate patient is paramount for a DCL. These are patients who manifest signs of instability such as hypotension, tachycardia, altered mental status, progressive coagulopathy, acidosis and hypothermia.[5] Aoki et al.[5] even went so far as to conclude that the purpose of DCL should be for correction of acidosis and coagulopathy and found mortality to be near 66% when these derangements were not corrected prior to definitive repair.

The procedure Stone et al.[4] advocated involved initial laparotomy with control of contamination and hemorrhage through the use of abdominal packing followed by ICU resuscitation with staged repair of injuries. The phrase “damage control laparotomy” was not coined until 1993 by Rotondo et al.[11] who detailed a three-stage approach. First, an immediate laparotomy is performed, with rapid abdominal packing and temporary closure. Second, physiologic stabilization is accomplished in the ICU with tertiary examination. Finally, definitive repair of injuries is completed after stabilization, which may require multiple operative procedures. In the rural setting, DCL can allow a rapidly deteriorating patient to be stabilized long enough to transfer them to a higher level center with more resources and capabilities.

While the application of DCL to the rural setting may seem logical, it is a relatively new concept. Even in the urban setting, DCL continues to evolve. The survival of patients who require DCL is tenuous at best. Johnson et al.[6] evaluated their own outcomes across a 10-year period. Specifically, they reviewed its use in exsanguinating penetrating abdominal injury and found that

Table 4
Hospital outcomes of patients that underwent a laparotomy before or after transfer for traumatic injury.

Parameter[a]	Treatment Group			P value
	Damage Control Laparotomy at Rural Facility	In Stable Condition with Laparotomy After Transfer	Unstable Condition with Laparotomy After Transfer	
Number	7 (15.6%)	30 (66.7%)	8 (17.8%)	–
ICU admission	6 (85.7%)	26 (86.7)	6 (75.0%)	0.717
ICU days[b]	8 (1–11)	2 (1–6.8)	1 (0.3–2.5)	0.481
Mechanical ventilator use	7 (100%)	17 (58.6%)	6 (75.0%)	0.097
Ventilator days[b]	5 (1–6)	1 (0–3)	1 (0.3–3.5)	0.794
Hospital LOS	13 (6–21)[a]	6.5 (5–23)[a]	1 (1–9)[b]	0.018
Mortality	1 (14.3%)[a]	1 (3.3)[a]	6 (75.0%)[b]	<0.001

ICU = intensive care unit, LOC = length of stay.
Values within rows with different superscript letters are different at the $P \leq 0.05$ level.
[a] Presented as number (%) or median (IQR).
[b] Only patients who were admitted to the ICU or were ventilated are included.

Table 5
Injuries and cause of death for patients that underwent a laparotomy before or after transfer for traumatic injury.

Injuries	Cause of death	Contributing factors
DCL patient: Grade 4 infrarenal aortic injury, transverse colon injury	Hemorrhage	
ELS patient: Mesenteric rupture	Anoxic brain injury	Hemorrhage
ELU patients:		
Pt 1: Basilar skull fracture, cervical spine fractures, splenic injury	Traumatic brain injury	Neurogenic shock, hemorrhage
Pt 3: Liver lacerations, superior mesenteric vein transection, pneumothorax	Hemorrhage	Ventricular fibrillation
Pt 4: Liver lacerations, renal hilum disruption, bilateral pneumothoraces, closed head injury	Traumatic brain injury	Hemorrhage
Pt 6: Splenic laceration, multiple orthopedic injuries, closed head injury	Traumatic brain injury	Hemorrhage
Pt 7: Abdominal evisceration, splenic avulsion, diaphragm rupture	Hemorrhage	
Pt 8: distal aortic laceration, grade 5 splenic laceration, renal injury	Hemorrhage	

Table 6
Discharge locations of patients that underwent a laparotomy before or after transfer for traumatic injury.

Discharge Location[a]	Treatment Group		
	Damage Control Laparotomy at Rural Facility	In Stable Condition with Laparotomy After Transfer	Unstable Condition with Laparotomy After Transfer
Number	7 (15.6%)	30 (66.7%)	8 (17.8%)
Death in Hospital	1 (14.3%)	1 (3.3%)	6 (75.0%)
Home	4 (57.1%)	20 (66.7%)	0 (0%)
Skilled Nursing Facility	0 (0%)	2 (6.6%)	0 (0%)
Mental Health Facility	1 (14.3%)	0 (0%)	1 (12.5%)
Rehabilitation Center	1 (14.3%)	3 (10.0%)	0 (0%)
Specialty Hospital	0 (0%)	3 (10.0%)	1 (12.5%)

[a] Presented as number (%).

patient survival improved from 58% to 90% over the ten years that DCL evolved and attributed this to improved resuscitation. However, most studies have not reported such high survival rates. Shapiro et al.[8] in a review of DCL in the literature to date, found consistent survival rates of 50%, but these studies focused on DCL in urban areas. As DCL has increased in utilization and effectiveness, it is logical that it would extend into the rural setting.

In theory, the decision to perform a DCL in a rural setting is based on the stability of the patient and the risk posed by delay in transfer to a higher level center for definitive treatment. If the benefits of immediate transfer to a higher tier facility outweigh these risks, then unstable patients who undergo an immediate laparotomy after transfer should have outcomes that are no worse than those who undergo DCL prior to transfer. However, multiple studies have determined that the length of time a patient is acidotic, coagulopathic, hypothermic and hemorrhaging negatively affect their survival.[5,6,9,11] While not specifically addressing DCL, Veenema and Rodewald discussed the importance of stabilizing rural patients at level III emergency departments before transfer to level 1 trauma center.[12] Using TRISS methodology, they were able to show that with stabilization at a level III facility, the number of actual deaths was less than the predicted number of deaths.[12] DCL should be included as a tool for stabilization.

The injuries identified during DCL can be quite variable. It is well-known that traumatic bowel injuries may not manifest clinically on initial evaluation. Computed tomography can also be inaccurate for diagnosis, especially for hollow viscus injuries. As with any perforated hollow viscus, repair must be performed, but delay is not as life-threatening as delay of other injuries.[13] Harmston et al.[13] performed a meta-analysis comparing mortality between early (8 h after injury) or delayed (more than 8 h after injury) repair. While the overall mortality of hollow viscus injury is 17%, there was no appreciable difference in mortality in regard to length of time between injury and repair. The majority of our stable for transfer patients sustained hollow viscus injury. Therefore, as is indicated in this study, these patients remain stable for transport, and definitive repair can be delayed without serious detriment to the patient. Indeed, in spite of the fact that the majority of these patients were transported with a hollow viscus injury, mortality for this group was 3.3%, well within the acceptable range for this injury type.

Vascular injuries can be significant and life-threatening. Major vascular injuries can quickly result in an unstable trauma patient, and if not controlled can in many cases result in avoidable death. The patients who were explored before transport did not have definitive repair of their vascular injuries. Injuries included iliac vein lacerations, distal abdominal aortic lacerations, inferior vena cava injuries, and mesenteric vein avulsion. Most were packed as a means of hemorrhage control and stabilization. In all likelihood, these DCLs served as a temporizing measure to facilitate transfer to a Level 1 trauma center, and in some cases were likely life-saving. On the other hand, ELU patients who were explored after transport had sustained similar vascular injuries such as iliac vein and artery lacerations, renal artery injury and inferior vena cava lacerations; however, all of these patients died as a result of their injuries. Carrillo et al.[14] found that patients with iliac vessel injury actually had improved outcomes if damage control in the form of packing was performed instead of repair at initial laparotomy. While their sample size was small, they found that DCL for vascular injuries had mortality of 9% versus 38% who had definitive laparotomy.

While this study has shown a lack of harm in DCL by rural surgeons, it cannot definitively state that DCL by a rural surgeon is always indicated. A key aspect of DCL is patient selection and this is made on a case by case basis. Rural surgeons need to take into account mechanism, injuries, travel time, and hospital resources. However, it is important to encourage rural surgeons that DCL can be utilized in unstable patients and may be life-saving. A key aspect is improving the confidence and competence in DCL for the rural surgeon. One way is through completion of an Advanced Surgical Skills for Exposure in Trauma (ASSET) course. These courses were developed in 2010 by ACSCOT as a way to provide surgical residents and surgeons experience with operative exposure techniques. The one-day course provides education and practice in major vasculature exposure and pelvic packing. These are exposures that the typical general surgeon does not practice regularly. A rural surgeon taking care of trauma patients should have these skills to use when necessary. One study reported that ASSET course participants have an increased rate of self-confidence after attendance.[15]

There are several limitations to this study. The retrospective format of this study introduces the chance of selection bias and information bias which could have altered the accuracy of our analysis between the DCL, ELU, and stable groups. In addition to this, the number of included subjects was fairly low, which could reduce the ability to detect statistically significant differences in outcomes between the three groups. The single center nature of this study introduces the possibility that our results could be rendered invalid if this study were duplicated by multiple other centers. Travel time to a level 1 trauma center is a key factor in determining whether an injured patient is first transported to a trauma center versus undergoing DCL; due to the retrospective nature of this study, travel time is one of several variables that could not be analyzed and might have affected the conclusions that could be drawn from the study. Additionally, competency and confidence of local general surgeon can affect patient overall outcome following DCL. A multicenter, prospective study including Level 1 trauma centers receiving rural trauma patients would help to further define the outcomes of DCL in the rural population.

Conclusions

Management of trauma patients may begin in the rural setting, with rural surgeons tasked with deciding on proceeding to the operating room versus transferring the patient to a higher level facility. This decision plays an important role in patient care and ultimately outcomes, especially in the unstable patient. In order to become more confident in proceeding with DCL, resources are available, including ASSET courses, for rural general surgeons to gain more competence and confidence in performing damage control laparotomies. Based upon the findings of this study rural DCL can be life-saving in the appropriate patients, particularly those with vascular injuries.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjsurg.2019.01.005.

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