ORIGINAL ARTICLE
Turk J Surg 2019; 35 (1): 54-61

Analysis of trauma patients with unplanned returns to the operating room

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ABSTRACT

Objective: Trauma patients undergoing damage-control surgery may have a planned return to the operating room. In contrast, little is known about unplanned returns to the operating room (uROR) in trauma. The aim of this study was to identify risk factors for uROR in trauma patients. It is hypothesized that blunt trauma patients with uROR have higher mortality when compared to penetrating trauma patients with uROR. Additionally, it is hypothesized that trauma patients with uROR after thoracotomy have higher mortality than patients with uROR after laparotomy.

Material and Methods: A retrospective analysis of the National Trauma Data Bank from 2011-2015 including any adult patient with an uROR was performed.

Results: From 3.447.320 patients, 9.269 (0.2%) were identified to have uROR. In a multivariable logistic regression analysis, 27 independent predictors were identified for risk of uROR with the strongest independent risk factor being compartment syndrome (OR= 10.50, CI= 9.35-11.78, p< 0.001). Blunt (compared to penetrating) mechanism was associated with higher risk for mortality in patents with uROR (OR= 1.69, CI= 1.14-2.51, p< 0.001) as was re-incision thoracotomy (RT) compared to re-incision laparotomy (RL) (OR= 2.22, CI= 1.29-3.84, p< 0.001).

Conclusion: The strongest risk factor for uROR in trauma is compartment syndrome. Both a blunt (compared to penetrating) mechanism and RT (compared to RL) are independent risk factors for mortality in patients undergoing an uROR.

Keywords: Unplanned return to the operating room, return to the operating room, re-incision thoracotomy, re-incision laparotomy, trauma

INTRODUCTION

A return to the operating room is associated with worse outcomes in surgical patients (1). Up to 50% of elective thoracic cases with a return to the operating room are related to technical failures with 27.3% requiring control of post-operative hemorrhage. These patients have a mortality rate of 5.6% (2). General surgery patients have been shown to have an unplanned return to the operating room (uROR) rate of 5.9% with a mortality rate as high as 33.7%. Up to 70% of uROR in general surgery patients may be related to surgical complications (3). Trauma patients undergoing damage control surgery often have a planned return to the operating room (4). However, the incidence and outcomes of uROR in the trauma population using a large national database has not previously been reported.

The kinematics of blunt trauma and the transfer of energy to the patient are fundamentally different than in penetrating trauma. The larger surface area over which the energy is dispersed can lead to widespread injury and increased severity compared to the localized destruction from penetrating trauma (5). Additionally, trauma patients that have suffered thoracic injuries have a higher rate of mortality particularly with a blunt mechanism of injury (6). Our primary objective was to identify risk factors for uROR in trauma patients. Additionally, it is hypothesized that blunt trauma patients with uROR have higher mortality when compared to penetrating trauma patients with uROR. Finally, it is hypothesized that trauma patients with uROR for re-incision thoracotomy (RT) have higher mortality than patients with uROR for re-incision laparotomy (RL).

Cite this article as: Grigorian A, Schubl S, Gabriel V, Dosch A, Joe V, Bernal N, et al. Analysis of trauma patients with unplanned returns to the operating room. Turk J Surg 2019; 35 (1): 54-61

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Received: 09.04.2018
Accepted: 08.08.2018
Available Online Date: 01.03.2019

DOI: 10.5578/turkjsurg.4182

MATERIAL and METHODS

This work was approved by the institutional review board of the University of California, Irvine. Informed consent was not necessary as this study involves a large national database with de-identified information. The National Trauma Data Bank (NTDB) is a multicenter registry of trauma centers in the United States maintained by the American College of Surgeons Committee on Trauma (7). All registered cases with uROR in the NTDB occurring between 2011-2015 were identified. Patients under 18 years of age were excluded. Trauma patients with uROR were compared to those without uROR. The primary outcome was mortality. Secondary outcomes evaluated included total hospital length of stay (LOS), intensive care unit (ICU) LOS, ventilator days, acute kidney injury (AKI), acute respiratory distress syndrome (ARDS), myocardial infarction (MI), pulmonary embolism (PE), deep vein thrombosis (DVT), pneumonia, cerebrovascular accident (CVA), urinary tract infection (UTI), compartment syndrome, severe sepsis, and surgical site infection (SSI). The relation between mortality and baseline patient demographics, comorbidities, injury profile, interventions and hospital outcomes including complications was analyzed.

Patient demographic information including age, gender and prehospital comorbidities were collected. Injury profile included the injury severity score (ISS), mechanism of injury and associated solid organ and extremity injuries. The interventions analyzed included RL and RT based on the appropriate International Classification of Diseases Version-9 procedure codes.

Student's t-test and Mann-Whitney U test were used to compare continuous variables and chi-square was used to compare categorical variables for bivariate analysis. Categorical data were reported as percentages, and continuous data were reported as medians with interquartile range. The magnitude of the association between predictor variables and primary outcomes was measured using a univariable logistic regression model. Covariates with statistical significance ($p \leq 0.20$) were selected into a multivariable logistic regression model. Confounding variables were controlled for using a hierarchical logistic regression model and risk analysis was reported with an odds ratio (OR) and 95% confidence intervals (CI). The reference group used in our logistic regression analysis to identify risk factors for uROR included all trauma patients in the dataset while the reference group for risk of mortality included only patients with uROR. All p values were two-sided, with a statistical significance level of < 0.05. All statistical analyses were performed with IBM SPSS Statistics for Windows, Version 24. (IBM Corporation, Armonk, USA).

RESULTS

Patient Demographics, Injury Profile and Primary Outcomes

From 3.447.320 patients, 9.269 (0.2%) were identified to have uROR with more occurring in penetrating traumas (0.67%) and less in blunt traumas (0.22%). There was an increased incidence of uROR for each consecutive year from 0.11% in 2011 to 0.31% in 2015 ($p< 0.05$). When compared to trauma patients without uROR, those with uROR were younger (median age, 45 vs. 50, $p< 0.001$) and had a higher median ISS (18.0 vs 6.0, $p< 0.001$). Majority of the patients in both groups were involved in blunt trauma. Trauma patients with uROR had higher rates of penetrating mechanism (25.2% vs. 10.2%, $p< 0.001$), hypotension on admission (10.4% vs. 2.9%, $p< 0.001$) and all associated injuries analyzed except for burn injury (1.3% vs. 2.3%, $p< 0.001$) (Table 1). Mortality rate was also higher in patients with uROR (11.8% vs. 3.7%, $p< 0.001$) and higher in patients with RT compared to RL (30.3% vs. 21.0%, $p< 0.05$) (Table 2).

Logistic Regression Analysis for Risk of uROR in Trauma Patients

In a multivariable logistic regression analysis, twenty-seven independent predictors were identified for risk of uROR in trauma patients. The strongest independent risk factors, in order, included compartment syndrome (OR= 10.50, CI= 9.35-11.78, $p< 0.001$), SSI (OR= 5.44, CI= 4.82-6.14, $p< 0.001$), severe sepsis (OR= 3.05, CI= 2.75-3.37, $p<0.001$) and colorectal injury (OR= 3.00, CI= 2.74-3.28, $p< 0.001$). Patients with a blunt mechanism had a lower risk for uROR compared to those with a penetrating mechanism (OR= 0.44, CI= 0.41-0.47, $p< 0.001$). Patients that were ≥ 65 years of age also had a lower risk of uROR (OR= 0.83, CI= 0.78-0.88, $p< 0.001$) (Table 3).

Logistic Regression Analysis for Risk of Mortality in Patients with uROR

In a multivariable logistic regression analysis, nine independent predictors were identified for risk of mortality in trauma patients with uROR. The strongest independent risk factors, in order, included MI (OR= 6.49, CI= 2.19-19.27, $p< 0.05$), CHF (OR= 5.32, CI= 2.07-13.69, $p< 0.05$), AKI (OR= 3.96, CI= 2.84-5.50, $p< 0.001$) and age ≥ 65 years (OR= 3.66, CI=2.47-5.42, $p< 0.001$). Blunt (compared to penetrating) mechanism was associated with higher risk for mortality in patents with uROR (OR= 1.69, CI= 1.14-2.51, $p< 0.001$) as was RT (compared to RL) (OR= 2.22, CI= 1.29-3.84, $p< 0.001$) (Table 4).

Secondary Outcomes in Trauma Patients with uROR

Compared to trauma patients without uROR, those with uROR had a longer LOS (18.0 vs. 3.0 days, $p< 0.001$), ICU LOS (10.0 vs. 3.0 days, $p< 0.001$) and higher rates of all in-hospital complications analyzed (Table 5).

DISCUSSION

This retrospective analysis, encompassing five years of NTDB data, provides an analysis of trauma patients undergoing uROR. The incidence of uROR has increased each year from 2011 to 2015 but remains low at 0.31% in the most recent year analyzed. Majority of the patients were involved in a blunt mechanism of

Table 1. Demographics and injury profile of trauma patients with and without an unplanned return to the operating room

Characteristic	- uROR (n= 3.438.051)	+ uROR (n= 9269)	p
Age, year, median (IQR)	50.0 (37)	45.0 (32)	< 0.001
Sex (male), n (%)	2.158.458 (62.8%)	7042 (76.0%)	< 0.001
Comorbidities, n (%)			
Congestive heart failure	107.411 (3.1%)	31 (2.5%)	< 0.001
Cerebrovascular accident	76.189 (2.2%)	177 (1.9%)	< 0.001
Diabetes	404.651 (11.8%)	1048 (11.3%)	0.17
Hypertension	993.094 (28.9%)	2443 (26.4%)	< 0.001
COPD	249.607 (7.3%)	648 (7.0%)	0.32
ISS, median (IQR)	6.0 (7)	18.0 (16)	< 0.001
Blunt mechanism, n (%)	2.860.547 (89.8)	6544 (74.8%)	< 0.001
Penetrating mechanism, n (%)	326.570 (10.2%)	2208 (25.2%)	<0.001
Hypotensive on admission (SBP < 90 mm Hg), n (%)	99.204 (2.9%)	965 (10.4%)	< 0.001
Injuries, n (%)			
Traumatic brain injury	1.025.301 (29.8%)	3337 (36.0%)	< 0.001
Spine	562.750 (16.4%)	2581 (27.8%)	< 0.001
Rib	522.407 (15.2%)	2505 (27.0%)	< 0.001
Upper extremity	618.191 (18.0%)	2245 (24.2%)	< 0.001
Lower extremity	808.142 (23.5%)	2630 (28.4%)	< 0.001
Lung	411.564 (12.0%)	2779 (30.0%)	< 0.001
Liver	85.203 (2.5%)	1190 (12.8%)	< 0.001
Spleen	87.965 (2.6%)	1196 (12.9%)	< 0.001
Esophagus	1368 (0.1%)	32 (0.3%)	< 0.001
Stomach	8752 (0.3%)	349 (3.8%)	< 0.001
Small intestine	28.778 (0.8%)	1078 (11.6%)	< 0.001
Colorectal	26.260 (0.8%)	1188 (12.8%)	< 0.001
Pancreas	2617 (0.1%)	172 (1.9%)	< 0.001
Kidney	44.193 (1.3%)	646 (7.0%)	<0.001
Burn	79.294 (2.3%)	117 (1.3%)	< 0.001
Crush	13.298 (0.4%)	101 (1.1%)	< 0.001

uROR: Unplanned return to operating room; IQR: Interquartile range; COPD: Chronic obstructive pulmonary disease; SBP: Systolic blood pressure; ISS: Injury severity score.

Table 2. Mortality rates of adult trauma patients

Population	Mortality, %
uROR	11.8%
No uROR	3.7%
Re-incision thoracotomy	30.3%
Re-incision laparotomy	21.0%

uROR: Unplanned return to the operating room.

injury. Multiple predictors were identified for risk of uROR but the strongest risk factor was compartment syndrome. In support of our hypothesis, it was demonstrated that both a blunt (compared to penetrating) mechanism and RT (compared to RL) are independent risk factors for mortality in patients undergoing an uROR.

Trauma patients with uROR have multiple injuries, which may not all be clinically apparent during primary/secondary surveys. We identified higher rates of nearly all associated injuries

Table 3. Multivariable analysis for risk of unplanned return to operating room in adult trauma patients

Predictor	OR	95% CI	p
Blunt vs. penetrating mechanism	0.44	0.41-0.47	< 0.001
Age ≥ 65	0.83	0.78-0.88	< 0.001
Upper extremity injury	1.07	1.01-1.13	< 0.05
Diabetes	1.11	1.03-1.20	< 0.05
Lung injury	1.16	1.09-1.24	< 0.001
Kidney injury	1.17	1.06-1.29	< 0.05
Myocardial infarction-complication	1.17	1.23-1.77	< 0.001
Hypotensive on admission	1.19	1.10-1.29	< 0.001
Hypertension-comorbidity	1.22	1.15-1.29	< 0.001
Spine injury	1.24	1.18-1.31	< 0.001
Liver injury	1.25	1.15-1.35	< 0.001
Traumatic brain injury	1.28	1.22-1.35	< 0.001
Pancreas injury	1.29	1.06-1.29	< 0.05
Lower extremity injury	1.37	1.31-1.45	< 0.001
Male gender	1.39	1.32-1.47	< 0.001
Stomach injury	1.46	1.27-1.67	< 0.001
Pulmonary emboli-complication	2.03	1.78-2.32	< 0.001
Acute kidney injury-complication	2.11	1.91-2.33	< 0.001
Esophagus injury	2.13	1.44-3.14	< 0.001
Urinary tract infection-complication	2.25	2.06-2.45	< 0.001
ISS > 25	2.26	2.12-2.41	< 0.001
Small intestine injury	2.55	2.33-2.79	< 0.001
Deep vein thrombosis-complication	2.62	2.40-2.86	< 0.001
Crush injury	2.63	2.11-3.30	< 0.001
Pneumonia-complication	2.81	2.62-3.01	< 0.001
Colorectal injury	3.00	2.74-3.28	< 0.001
Severe sepsis-complication	3.05	2.75-3.37	< 0.001
Surgical site infection	5.44	4.82-6.14	< 0.001
Compartment syndrome	10.50	9.35-11.78	< 0.001

ISS: Injury severity score; OR: Odds ratio; CI: Confidence interval.

analyzed except for burn injuries in patients with uROR. Injury profile coupled with more severe trauma experienced by patients with uROR likely provided the "perfect-storm" for occult and missed injuries, which may have presented later requiring uROR. This is particularly true in patients with TBI or spine injury since these patients often have unreliable clinical exams (8,9). False-negative rates may continue to be high on subsequent exams. Houshian et. al have performed a retrospective analysis over four years at a Level-1 trauma center and found that 14%, 38% and 48% of injuries are missed in primary, secondary and tertiary surveys, respectively (10). In support of these reports, it was found in the present study that uROR had significantly higher rates of TBI and spine injury. Additionally, trauma patients with TBI were found to have a 28% increased risk for uROR while those with spine injury have a 24% increased risk for uROR. However, the most significant risk factor for uROR was compartment syndrome. This complication is unique because diagnosis is often made clinically without any widespread, highly sensitive or specific imaging or diagnostic modalities to help clinicians. Vigilance and good clinical judgment, especially determining the need for a prophylactic fasciotomy remain the hallmarks of management (11). The difficulty in diagnosing patients correctly may be responsible for the high risk of uROR. For this reason, almost 90% of cases involving compartment syndrome that reach litigation have a delay in diagnosis (12).

Table 4. Multivariable analysis for risk of mortality in adult trauma patients with an unplanned return to operating room

Predictor	OR	95% CI	p
Deep vein thrombosis-complication	0.31	0.18-0.53	< 0.001
Urinary tract infection-complication	0.34	0.21-0.57	< 0.001
Pulmonary emboli-complication	0.39	0.18-0.85	< 0.05
Pneumonia-complication	0.49	0.35-0.69	< 0.001
Blunt vs. penetrating mechanism	1.69	1.14-2.51	< 0.001
ARDS-complication	2.10	1.41-3.11	< 0.001
ISS ≥ 25	2.11	1.53-2.92	< 0.001
Re-incision thoracotomy vs. re-incision laparotomy	2.22	1.29-3.84	< 0.001
Hypotensive on admission	2.34	1.74-3.16	< 0.001
Age ≥ 65	3.66	2.47-5.42	< 0.001
Acute kidney injury-complication	3.96	2.84-5.50	< 0.001
Congestive heart failure-comorbidity	5.32	2.07-13.69	< 0.05
Myocardial infarction-complication	6.49	2.19-19.27	< 0.05

ARDS: Acute respiratory distress syndrome; ISS: Injury severity score.

Table 5. Analysis of clinical outcomes in trauma patients with and without an unplanned return to the operating room

Outcome	- uROR (n= 2290)	+ uROR (n= 6698)	p
LOS days, median (IQR)	3.0 (4)	18.0 (21)	< 0.001
ICU days, median (IQR)	3.0 (4)	10.0 (15)	< 0.001
Ventilator days, median (IQR)	3.0 (7)	8.0 (13)	< 0.001
Complications, n (%)			
Acute kidney injury	22.774 (0.7%)	723 (7.8%)	< 0.001
ARDS	28.466 (0.8%)	559 (6.0%)	< 0.001
Deep vein thrombosis	25.911 (0.8%)	869 (9.4%)	< 0.001
Pulmonary emboli	11.055 (0.3%)	310 (3.3%)	< 0.001
Surgical site infection	5382 (0.2%)	435 (4.7%)	< 0.001
Urinary tract infection	49.157 (1.4%)	840 (9.1%)	< 0.001
Myocardial infarction	7957 (0.2%)	79 (0.9%)	< 0.001
Compartment syndrome	7358 (0.2%)	472 (5.1%)	< 0.001
Pneumonia	71.001 (2.1%)	1812 (19.5%)	< 0.001
Severe sepsis	10.866 (0.3%)	705 (7.6%)	< 0.001
Mortality, n (%)	125.041 (3.7%)	1090 (11.8%)	< 0.001

uROR: Unplanned return to operating room; LOS: Length of stay; ICU: Intensive care unit; IQR: Interquartile range; ARDS: Acute respiratory distress syndrome.

Most of the patients with uROR in our study were involved in blunt trauma. In support of previous reports, we demonstrate that blunt trauma carries a higher risk for mortality compared to penetrating trauma (13-17). A blunt mechanism of injury has the potential for multi-system injury and often involves TBI, which is considered one of the leading causes of death in trauma patients (18-20). Almost half the patients in our study with blunt trauma undergoing uROR had an accompanying TBI and nearly 60% of blunt trauma patients undergoing uROR that died had a TBI diagnosis. Furthermore, blunt trauma patients with uROR had a significantly higher rate of extremity fractures (64.9% vs. 24.2%) when compared to patients with uROR after penetrating trauma, which may predispose them to more bleeding. Femur fractures undergoing surgical fixation require, on average, more

than three units of packed red blood cells due to peri-operative blood loss (21). Lastly, the trajectory of a penetrating injury is often easily found upon surgical exploration allowing for the early identification of all significant injuries. Patients with blunt trauma may have an occult injury without other surrounding associated injuries leading to increased mortality associated with delays in diagnosis (22-24).

Thoracic trauma has been shown to be involved in up to 50% of trauma-related deaths (25-27). In our study, we were able to demonstrate that trauma patients enduring uROR for RT had higher risk for mortality compared to patients undergoing uROR for RL. A previous study has demonstrated hemorrhage as the predominant factor requiring uROR for RT (2). Since hemorrhage is also the number one cause of mortality in trauma patients in general, it follows that uROR for RT had a higher mortality rate compared to those who underwent RL (28). Pujol et al. have reported that technical skills and expertise contribute to uROR and therefore, this may be a factor contributing to the increased mortality rate as well (29). From 2007-2015, there were 137.575 patients who underwent exploratory laparotomy in the NTDB while only 21.579 cases of exploratory thoracotomy were reported. A possible explanation for increased mortality in the RT group is that trauma surgeons have less experience working in the chest. Additional studies stratifying outcomes of uROR based on the operating surgeon's volume of thoracotomy cases appears warranted.

The overall mortality rate in our study population of trauma patients undergoing uROR was 11.8%, which is significantly lower than the reported mortality rate in general surgery patients undergoing uROR (33.7%) (3). These populations are quite different and the reason for this disparity is undoubtedly multifactorial. Some possible explanations include that the median age of trauma patients with uROR in the NTDB was lower than the aforementioned general surgery cohort (45 vs. 61 years), and the nature of the reason of the uROR may be very different (i.e. hemorrhaging trauma patients versus infection) (3).

The rate of uROR may be useful for comparison of hospital outcomes and for identifying opportunities for quality improvement (30). Our study identified an alarming trend of increased annual incidence of uROR. This is concerning as uROR poses a financial burden on the patient and a strain on hospital resources. An uROR has been shown to be associated with an eightfold increase in hospital readmission (31). In order for uROR to be a comparable metric across institutions, data collection must include documentation of the surgical findings at re-exploration, as well as the interventions performed. Only with this data can a comparison of results between centers yield meaningful quality improvement by demonstrating how high performing centers can achieve improved outcomes comparatively to low performing centers.

Study Limitations

There are several limitations to our study including those inherent to retrospective large databases such as participation being voluntary and coding error, which may lead to misclassification bias due to the under-reporting of pre-existing medical conditions and complications. Furthermore, our analysis was restricted to data fields available in the NTDB and were subject to input error. We were also missing important data such as timing of the index operation and reason for and time of uROR. Therefore, adjustment for these potential confounders was not possible. Finally, because this was an observational study, the role of unmeasured or unobserved confounding variables cannot be excluded.

CONCLUSION

Trauma patients undergoing uROR appears to be on the rise. Most patients are involved in a blunt mechanism. Multiple predictors were identified for risk of uROR, but the strongest risk factor was compartment syndrome. Both a blunt (compared to penetrating) mechanism and RT (compared to RL) are independent risk factors for mortality in patients undergoing uROR. The overall mortality in trauma patients undergoing uROR is less than emergency general surgery patients undergoing uROR. Future prospective research regarding uROR in all trauma patients appears warranted to better elucidate the exact causes and interventions to prevent and/or successfully treat uROR in trauma patients.

Ethics Committee Approval: This study was approved by the Institutional Review Board at the University of California, Irvine.

Informed Consent: This research involved humans. However, since this retrospective study was performed using a national database with deidentified patients, risk to participants is minimal. There is no consent required.

Peer-review: Externally peer-reviewed.

Author Contributions: Consept - A.G., S.S., J.N.; Design - A.G., S.S., J.N.; Supervision - J.N.; Data Collection and/or Processing - A.G., T.D.; Analysis and Interpretation - A.G., S.S., V.G., A.D., V.J., T.D., N.B., J.N.; Literature Search - A.G., J.N.; Writing Manuscript - A.G.; Critical Reviews - A.G., S.S., V.G., A.D., V.J., N.B., T.D., J.N.

Conflict of Interest: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

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ORİJİNAL ÇALIŞMA-ÖZET
Turk J Surg 2019; 35 (1): 54-61

Travma hastalarında plansız ameliyathaneye dönüş analizi

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ÖZET

Giriş ve Amaç: Hasar kontrol cerrahisi geçiren travma hastalarında ameliyathaneye planlı bir dönüş olabilir. Bunun aksine, travmada plansız ameliyathaneye dönüşler (PAD) hakkında çok az şey bilinmektedir. Bu çalışmanın amacı, travma hastalarında PAD risk faktörlerini belirlemekti. Ayrıca, plansız ameliyathaneye dönüşlü künt travma hastalarının plansız ameliyathaneye dönüşlü penetran travma hastalarına kıyasla daha yüksek mortalite oranına sahip olduğu varsayımında bulunduk. Buna ek olarak, torakotomi yapılan PAD travma hastalarının laparotomi yapılan hastalara oranla daha yüksek mortaliteye sahip olduğu da öne sürülmüştür.

Gereç ve Yöntem: 2011-2015 yılları arasını kapsayacak şekilde Ulusal Travma Veri Bankasının plansız ameliyathaneye dönüşlü erişkin hastaların verileri üzerine geriye dönük analiz yapıldı.

Bulgular: 3.447.320 hasta içerisinde 9269 (%0.2)'unun plansız ameliyathaneye dönüşlü hastalar olduğu belirlendi. Çok değişkenli lojistik regresyon analizinde, kompartıman sendromunun (OR= 10.50, CI= 9.35-11.78, p< 0.001) en güçlü bağımsız risk faktörü olduğu 27 bağımsız risk faktörü saptandı. Reinsizyon laparotomiye kıyasla reinsizyon torakotomide de olduğu gibi (OR= 2.22, CI= 1.29-3.84, p< 0.001) (penetran mekanizmaya kıyasla) künt mekanizma, plansız ameliyathaneye dönüşlü hastalarda daha yüksek mortalite riski ile ilişkiliydi.

Sonuç: Travmada PAD için en güçlü risk faktörü kompartıman sendromudur. Plansız ameliyathaneye dönüşlü hastalarda hem penetran mekanizmaya kıyasla künt mekanizma hem de reinsizyon laparotomiye kıyasla reinsizyon torakotomi bağımsız risk faktörlerini oluşturmaktadır.

Anahtar Kelimeler: Plansız ameliyathaneye dönüş, ameliyathaneye dönüş, reinsizyon torakotomi, reinsizyon laparotomi, travma

DOİ: 10.5578/turkjsurg.4182