

Objective model to facilitate designation of military–civilian partnership hospitals for sustainment of military trauma readiness

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ABSTRACT

Background A major dilemma of the military surgeon is the requirement for battlefield trauma expertise without regular exposure to a traumatically injured patient. To solve this problem, the military is partnering with civilian trauma centers to obtain the required trauma exposure. The main objective of this article is to quantify institutional differences and develop a predictive model for estimating the number of 24-hour trauma shifts a surgeon must be on call at civilian centers to experience urgent trauma cases.

Methods Trauma databases from multiple institutions were queried to obtain all urgent trauma cases occurring during a 2-year period. A predictive model was used to estimate the number of urgent surgical cases in multiple specialties surgeons would experience over various numbers of 24-hour shifts and the number of 24-hour shifts required to experience a defined number of cases. Results Institution 1 had the lowest number of required 24-hour shifts to experience 10 urgent operative cases for general/trauma surgery (10 calls) and orthopedic surgery (6 calls) and the highest number of predicted cases over 12 days, 18.3 (95% CI 11 to 27), with 95% confidence. The expected trauma cases and 24-hour shifts at Institution 1 were statistically significant ($p < 0.0001$). There were seasonal effects at all institutions except for Institution 3.

Discussion There are significant variabilities in trauma center volume and therefore, the expected number of shifts and cases during a specific period of time is significantly different between trauma centers. This predictive model is objective and can therefore be used as an extrapolative tool to help and inform the military regarding placement of personnel in optimal centers for trauma currency rotations.

Level of evidence Economic and value-based evaluations, level II.

BACKGROUND

Today's military faces the challenge of needing trauma expertise to expertly manage those seriously wounded on the battlefield; however, military hospitals stateside lack the trauma volume to maintain this expertise. The delivery of adept trauma care in the deployed environment and the skill set to perform life-saving interventions on combat casualties require a unique set of abilities executed when minutes matter most. During interwar periods when there are low combat casualty volumes, this unique skill set has to be acquired and sustained.

A well-described dilemma of the military surgeon is this requirement for battlefield trauma expertise without regular exposure to a traumatically injured patient.¹ This challenge was recognized at the national level in the National Defense Authorization Act for Fiscal Year 2017 (NDAA 2017), which defined a requirement for increased training of military surgeons in civilian trauma centers. Such challenges resonate strongly in both the military and civilian surgical communities, and in solidarity, military–civilian trauma partnerships have been viewed as mutually beneficial. Military efforts as well as national efforts supporting this bidirectional improvement in civilian and battlefield trauma care are being spearheaded by the Military Health System Strategic Partnership with American College of Surgeons (MHSSPACS), Department of Defense Joint Trauma System, the Zero Preventable Death campaign to develop a national trauma system, and the Mission Zero Act, which seeks to fund military–civilian partnerships (MCP).^{2–4}

Civilian surgeons have a similar burden of maintaining a 'trauma readiness' posture given the uncertain nature of today's society and the risk of mass shootings, transit mishaps, and natural disasters. Civilian general surgeons and residents must obtain and maintain trauma skills and may face similar challenges as military surgeons. Many general surgery residency programs must send their residents to separate institutions for trauma center rotations to meet residency review committee requirements for trauma operations and trauma patient management. The question of how medical professionals best obtain trauma experience is fundamental to addressing these challenges. If medical professionals were to travel to obtain the necessary experience, the characteristics of the institution would directly affect the training; however, such characteristics of trauma centers in terms of case volume and the length of rotation required have not been defined.

There are currently pre-existing service-specific (Army, Navy and Air Force) and many others are in development. Expanding "trauma sustainment MCPs (TS-MCP)" has been embraced with enthusiasm but there is no joint (from a military perspective) or national guidelines. The MHSSPACS has established a work group leveraging on the experience of subject matter experts and has published on these efforts in evaluating trauma center characteristics and developing standards for suitable TS-MCPs.³ While specific types and volume of

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trauma cases in deployed and stateside hospitals have been reported, the question regarding case volume influence of where to train and how much experience is needed to maintain the skills necessary to be a successful trauma surgeon has not been addressed. A method for predicting course duration at suitable training centers is required. Additionally, differences in course duration at potential trauma centers suitable for TS-MCPs should be established prior to selection of new training centers. This study primarily aims to develop a predictive model to estimate and compare the durations of theoretical trauma readiness courses by applying it to four trauma centers. This predictive model will allow military and civilian organizations to identify a necessary threshold of urgent trauma operations to select training locations and design trauma readiness programs. While predicted case volume is not the only factor determining success of TS-MCPs, having these data will provide an objective and relevant criterion.

METHODS

After non-human research determination, data from trauma registries at four participating institutions were obtained and analyzed. These institutions were identified based on military association and willingness of their trauma registries to provide information based on study criteria. Identities have been withheld to prevent any bias in further military partnerships. Previously used methods were replicated with several definitions made *a priori*.⁵

Urgent surgical operation in traumatically injured patients was selected as the intervention of interest most closely representing the role of forward-deployed surgeons.^{1 6-9} The most common scenario for deployed forward surgical teams includes a general and an orthopedic surgeon with a small team consisting of four to eight additional personnel in an austere far-forward, resource-constrained environment with little or no patient holding capacity. These ‘damage control’ surgical units are used strategically on the battlefield to bridge the time/space gap between wounding and definitive care; they provide initial resuscitation, hemorrhage control, contamination control, and long-bone fracture stabilization for patients transferring to higher levels of care. For the purposes of this analysis, an urgent operation was defined as an operation that occurred on the day or the following day (one calendar day) of admission. A calendar day instead of a strict 24-hour separation between admission and operations was used to define an urgent case during a 24-hour shift due to uncertainty in the accuracy of time of day measurements in trauma registries.

It has been previously confirmed that seasonality may affect the frequency of urgent operations, but it may not impact all specialties.⁵ For each surgical specialty examined, seasonality was tested for each institution and, where appropriate, further analysis was done to determine the anticipated number of days required to experience a certain number of cases and to estimate how many cases would be experienced during a specified number of days. Given there are little data to discern adequate case volume for a general surgeon to be ‘proficient’ in trauma, we chose 10 operative trauma cases as an initial benchmark, the number mandated by Accreditation Council for Graduate Medical Education (ACGME) for general surgery graduation, but considered other possible case volumes above and below this number.¹⁰⁻¹² Additional case volume scenarios were analyzed, defining competency as exposure to ‘X’ cases per year, where ‘X’ = 5, 10, 12, or 20 cases, respectively. Since a training program and readiness metric require some level of certainty for course

planning, predictions were made with a goal of 95% confidence. The initial data that sought from institutions were data from October 1, 2015 to September 30, 2017. One institution (Institution 3) did not have available data from this exact time frame, and instead a set from January 1, 2016 to December 31, 2017, was used.

Non-parametric bootstrap simulation methods were used to evaluate the distribution of the observed data set, which is assumed to represent the population and future years. The observed data were resampled with replacement 10,000 times to estimate a sampling distribution. Given that the precision of the bootstrap estimates is determined by the precision of the original sample, 10 000 resamples were determined to be sufficient, and additional samples were unlikely to change the estimates. Poisson regression was used to investigate whether seasonal variation existed in the observed 2-year data for general/trauma surgery, orthopedic, and neurosurgery cases at each hospital and to investigate whether seasons, days of the week, and the interactions of seasons and years and days of the week and year were significantly associated with counts of surgical cases. If overdispersion was observed in the data, a negative binomial model was used instead. All models met the goodness of fit criteria for Poisson and negative binomial regression. For the variable season, spring was defined as March, April, and May, summer was defined as June, July, and August, fall was defined as September, October, and November, and winter was defined as December, January, and February.

The number of call days needed for a surgeon to experience a variable number of urgent cases and the average number of urgent cases per 24-hour call period were estimated using bootstrap resampling methods, and scenarios hypothesizing a number of shifts and expected number of cases, along with 95% CI, were listed. For scenarios requiring a preset number of cases and asking how many days were required, the number of days required was determined to be the number at which the minimum number of a one-sided 95% CI was the preset number of cases. The upper bound of the one-sided 95% CI was estimated and determined to be the maximum expected number of days it would take to see X number of cases with a 95% level of confidence.

RESULTS

For each institution, the total numbers of urgent operative trauma-related cases were identified for trauma/general surgery, orthopedics, and neurosurgery for each day. For all institutions, urgent orthopedic cases were the most frequent, followed by trauma/general surgery and finally neurosurgery. A seasonal variation in the number of urgent cases was demonstrated for trauma/general surgery at Institution 2, Institution 4, and Institution 1. There was no seasonal variation at Institution 3. In all scenarios where seasonal variation was noted, the interaction between season and year was not statistically different in the Poisson and negative binomial models, indicating that these seasonal trends were constant across all years analyzed. At the institutions where seasonal variation was demonstrated for trauma/general surgery, summer was the highest volume time. For those specialties and locations with seasonal variation, the number of cases that could be expected over defined intervals and the days required to experience a defined number of cases with a 95% CI were calculated for each season. For those without seasonal variation, an overall measurement of the data set was tabulated. For those with seasonal effect, the optimum seasonal numbers for trauma/

Table 1 Anticipated number of cases during specified number of shifts and the number of days to experience the specified number of cases with 95% confidence. For trauma/general surgery, significantly more cases occurred in the summer season for all institutions except for Institution 3

Trauma/general surgery				
	Institution 1	Institution 2	Institution 3	Institution 4
Number of 24-hour shifts	Expected number of urgent cases (95% CI)			
5	7.7 (3 to 13)	4.0 (1 to 8)	3.9 (0 to 9)	3 (0 to 9)
10	15.3 (8 to 23)	8.0 (3 to 14)	7.7 (2 to 15)	7 (1 to 14)
12	18.3 (11 to 27)	9.7 (4 to 16)	9.3 (3 to 17)	8 (2 to 16)
20	30.6 (20 to 42)	16.1 (9 to 24)	15.5 (7 to 25)	14 (6 to 24)
Minimum number of cases	24-hour shifts resulting in a 95% certainty of experiencing at least the stated minimum number of cases			
5	6	12	13	16
10	11	20	22	26
20	19	35	38	44

general surgery were tabulated instead of overall numbers (tables 1–3). Urgent neurosurgery procedures are substantially less frequent than orthopedics and trauma/general surgery. In a previous study, neurosurgery was the third most frequent specialty performing urgent trauma cases, with other specialties such as otolaryngology, ophthalmology, urology, and so on, being even less.⁵

The institutions were compared with regard to seasonality. Results from the Poisson regression model show that institutions are significantly associated with counts of each surgery type ($p < 0.0001$), meaning that frequency of surgery type is dependent on the hospital. Assigning Institution 1 as the reference category, it was found to be significantly different from the other institutions and also had a significantly higher rate of experiencing urgent cases for general surgery/trauma, orthopedics, and neurosurgery in comparison to the other three hospitals, which is quantified by the negative value regression coefficients seen in table 4.

Table 2 Anticipated number of cases during specified number of shifts and the number of days to experience the specified number of cases with 95% confidence. Season did not have a significant effect for orthopedics

Orthopedics				
	Institution 1	Institution 2	Institution 3	Institution 4
Number of 24-hour shifts	Expected number of urgent cases (95% CI)			
5	13.9 (7 to 21)	10.1 (4 to 17)	6.4 (2 to 12)	5.2 (1 to 10)
10	27.8 (18 to 38)	20.3 (12 to 30)	12.7 (6 to 21)	10.3 (5 to 17)
12	33.3 (23 to 45)	24.4 (15 to 34)	15.2 (8 to 24)	12.4 (6 to 19)
20	55.5 (42 to 70)	40.7 (29 to 54)	25.4 (15 to 36)	20.6 (12 to 30)
Minimum number of cases	24-hour shifts resulting in a 95% certainty of experiencing at least the stated minimum number of cases			
5	4	10	8	9
10	6	16	13	16
20	10	29	23	27

Table 3 Anticipated number of cases during specified number of shifts and the number of days to experience the specified number of cases with 95% confidence. Season did not have a significant effect for neurosurgery

Neurosurgery				
	Institution 1	Institution 2	Institution 3	Institution 4
Number of 24-hour shifts	Expected number of urgent cases (95% CI)			
5	2.3 (0 to 6)	1.2 (0 to 4)	1.3 (0 to 4)	0.7 (0 to 3)
10	4.7 (1 to 9)	2.5 (0 to 6)	2.6 (0 to 6)	1.3 (0 to 4)
12	5.7 (2 to 11)	3.0 (0 to 7)	3.2 (0 to 7)	1.6 (0 to 5)
20	9.4 (4 to 16)	5.0 (1 to 10)	5.3 (1 to 10)	2.6 (0 to 6)
Minimum number of cases	24-hour shifts resulting in a 95% certainty of experiencing at least the stated minimum number of cases			
5	19	37	35	73
10	33	64	59	124
20	59	113	105	218

For each institution, the variance in the amount of cases between seasons varied substantially between institutions for general surgery/trauma cases, with the greatest variability at Institution 4 (figure 1).

DISCUSSION

The expertise to manage a traumatically injured patient requires judgment for which experience is foundational. While it is understood that the range of skills required to manage the severely injured polytrauma patient has a perishable component, sustainment of these skills for military deployment readiness is a challenge facing the military community.^{13 14} Trauma training and ongoing practice opportunities with MCPs are needed to maintain trauma skills for medical personnel; furthermore, they are statutory and mandated in section 708 of NDAA 2017. Many ongoing efforts are underway to develop new, and leverage

Table 4 Results of Poisson regression to examine statistical difference in counts of surgery types among hospitals over 2 years. Seasonality was included in the model but omitted from the table

Institution	Regression coefficients	P value
Trauma/general surgery		
1*		
2	−0.6033	<0.0001
3	−0.5131	<0.0001
4	−0.9672	<0.0001
Orthopedics		
1*		
2	−0.3080	<0.0001
3	−0.7798	<0.0001
4	−0.9911	<0.0001
Neurosurgery		
1*		
2	−0.6366	<0.0001
3	−0.5833	<0.0001
4	−1.2763	<0.0001

*Reference category; significance level is $p < 0.05$; control variables days of the week and season were omitted from the table.

Number of 24-Hour shifts expected in order to obtain 10 urgent operative Trauma/General Surgery Cases by season with 95% Level of Confidence

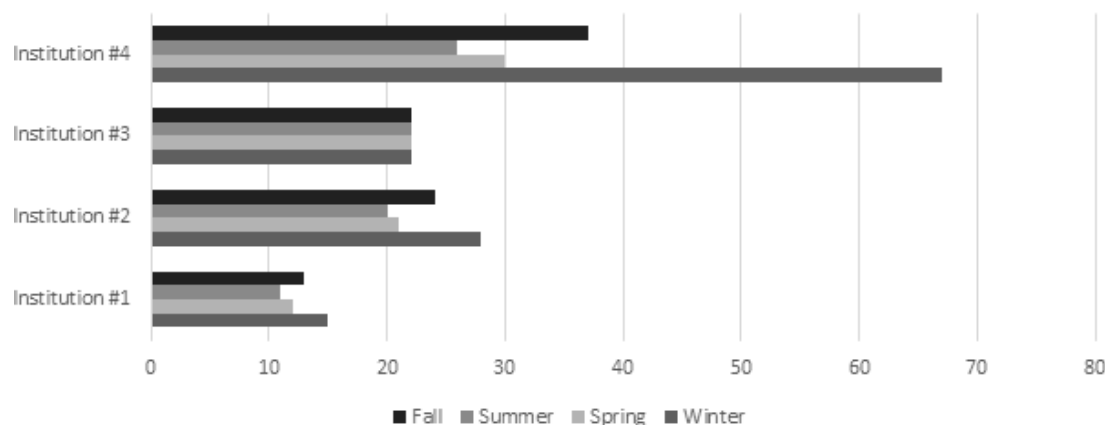


Figure 1 Graphical depiction highlighting the seasonal variation in number of predicted 24-hour shifts to achieve 10 trauma/general surgery urgent cases with 95% level of confidence.

existing, TS-MCPs. An objective method to determine ‘trauma case exposure’ should be used as an initial determination criterion as emerging TS-MCPs are being developed. This objective method will help inform the military regarding suitable locations and rotation duration for TS-MCPs. Additionally, it will enable standardization and help set metrics for case volume required to facilitate sustainment of readiness. We describe a method to identify the expected number of emergency trauma cases and call days needed to meet training goals and to calculate the timing and duration rotations at MCPs based on the institution’s historic case frequency by surgical specialty.

This study demonstrates that the training experience varies according to the season, the trauma center location, and the surgical discipline. For trauma/general surgery, there was a wide disparity between the level 1 trauma centers evaluated in this study, with Institution 1 having the greatest frequency of urgent trauma operations. The difference between trauma centers was less for orthopedics, but it remained significant. Using the ACGME requirement of 10 cases for general surgeons to maintain trauma competency, a trauma center rotation that is roughly 3 weeks long (allowing for a rotator sleep between shifts) or 2 weeks for orthopedics would seem suitable for a trauma readiness course and feasible in locations with a trauma volume similar to Institution 1. For other institutions, a longer rotation would be needed to meet the same training goals. However, for institutions where trauma is not as frequent, training programs can use these methods to plan lengths of trauma rotations to plan educational minimums.

A definition of an adequate number of cases for a general surgeon to be ‘proficient’ in trauma is undefined and ambiguous at best; there are little objective data to answer this question. Although arbitrary, and difficult to correlate with trauma readiness for deployment operations, 10-operative trauma was selected as an initial target for this to objectify a starting point, but expanded to include other possible totals.^{10–12} Despite being the number mandated by the ACGME for residency graduation, it is unlikely that this is the case volume which would result in a trained surgeon (in non-trauma practice) retooled for deployment. Surgeon ‘trauma-readiness’ for combat operations is certainly multifactorial; while it would be ideal to have

an objective case volume criterion, metrics for overall trauma capability and effectiveness of TS-MCP remain ambiguous and more likely reflective of the overall trauma experience. Projects are currently ongoing to develop methods for this type of assessment, which ideally will lead to a verification process for the TS-MCPs. So, while the absolute number is a starting target at best, the model is expected to evolve with the refinement of TS-MCPs. Alterations to the model could include specific case types and different numbers of operative goals, but the accuracy of any models would need to be established. Additionally, given the multitude of ongoing projects the military is using to help better define readiness, the most notable being the KSA (Knowledge, Skills and Abilities) Project, as KSAs for general surgeons get defined, TS-MCPs can use these objective criteria cross-walked with the current case volume to ensure a ‘readiness’ standard is being met. However, without minimal operative cases thresholds, there is no starting point to assess TS-MCPs.

The number of urgent trauma cases is only one measure of trauma training experience, and many other factors are important in gaining trauma expertise and for the success of TS-MCPs. How to develop successful TS-MCPs is multifactorial, pivoting on institutional leadership, investment of institution, military relationship, educational culture, and individual relationships. Some trauma centers may be saturated with learners all competing for the same opportunities, and a rotating provider placed into that environment may be only allowed to observe. Although some learning may be expected from observation, the impact of such an experience may not be substantial.¹⁵ An ideal learning environment would be a location where clinical decisions have a real and direct impact on trauma care that provides experiential learning.¹⁶ An institution with only slightly fewer predicted urgent cases, but more experiential learning opportunities or other positive attributes, may be the optimal location.

There is unlikely a single paradigm for a TS-MCP, and individualization of training will be necessary to meet the training and readiness gaps of surgeons. One model that the authors endorse is a training paradigm where the rotating surgeon serves as junior faculty or ‘fellow,’ making clinical decisions

with responsibility for intervening, with a co-call experienced surgeon, who may be military cadre permanently stationed at the civilian facility, providing mentorship and guidance. Ideally, such a rotation would be based at locations that can predictably provide at least 10 cases within a month with 95% confidence based on this article's methods. As part of this program, process improvement and student evaluations would be required to determine if 10 cases are too little or too much to obtain competence. How to gauge the quality of experiences and educational outcomes requires further study, but likely will involve objective and subjective criteria including: supervision, evaluations, peer review, and self-assessment.¹⁷

The seasonal effect on trauma can impact the experience obtained at an institution if courses are held year-round with a set expectation of case experiences. If an institution has large differences in peaks and troughs of urgent trauma cases, the number of urgent trauma cases experienced during a rotation may vary substantially. Not considered in this study, but potentially important, are the time of day and day of the week when urgent trauma cases occur. It is known that day of the week has some effect using this type of predictive model.⁵ For surgeons who are able to access trauma center call in their local area, knowledge of the most active trauma days may improve their ability to schedule call and obtain a higher volume of urgent cases. Likewise, if urgent trauma cases most commonly happen at night, a rotation could be established to have rotating surgeons on call only at night and resting in the day. This would eliminate prolonged downtime and shorten the length of the course. However, paradoxically, intermittent involvement without immersion into the other educational opportunities and the lack of covering the full spectrum of trauma care to focus only on operative cases may reduce the level of responsibility given to rotating surgeons and reduce educational and mentorship opportunities.

The main weakness of this study is that this predictive model focuses only on urgent surgical trauma cases and does not assess the full spectrum of learning experiences that may be obtained during a TS-MCP rotation. Additional features of a program may be important for developing surgeons with the technical skills and 'trauma mentality' attributes to deploy to potentially resource-limited and austere environments. Second, the future is not fully predictable, and the optimal length of data input into the analysis is unknown. With longer time frames, older data are used that may not reflect current socioeconomic, medical care usage, population and cultural changes within the catchment area of a trauma center, whereas shorter time frames may include too many random spikes. In addition, using a 'calendar day' in the model, we think, overcomes inaccuracy in time records but may slightly overestimate the number of urgent cases. Further studies validating this approach and assessing its accuracy are required. Follow-on studies, as well as validation of these methods, will continue to be informative; a broad analysis of all level 1 and level 2 trauma centers using Trauma Quality Improvement Program (TQIP) data further helps elucidate suitable TS-MCPs. Additional analyses could also examine operative case categories at TS-MCPs compared with the anatomic case type and operative workload distribution seen during deployment.¹² The caveat to further trying to predict and require specific case types will be inherently longer than the current estimates presented in this study. In addition to the analysis of types of trauma cases, analysis of the daily and weekly time distribution of urgent trauma cases may also be beneficial; having a crude predictive

capability for case volume and acuity would be beneficial beyond rotation planning for TS-MCPs.

Trauma experience should be an absolute, unwavering requirement for military surgeons expected to deploy and care for the traumatically injured. Ideally, TS-MCPs must be enduring to ensure military surgeons have the opportunity to maintain currency and competency in battlefield trauma care delivery. When there is no opportunity for continuous ongoing trauma practice, periodic rotations at TS-MCPs will help maintain trauma proficiency and ideally expertise. The predictive model presented in this article can be used to plan the duration of TS-MCP rotations and potentially be indicative of trauma centers most conducive in supporting TS-MCPs.

CONCLUSIONS

Given the significant differences in predicted urgent trauma cases between institutions, objective metrics can help inform regarding optimal trauma centers for TS-MCPs. Expected operative trauma exposure is an objective measure that should be used in determining locations. Institutions most suitable for TS-MCPs should be assessed on the operative volume and the time required to achieve a standardized TS-MCP trauma case exposure goal. Using the novel predictive model described, locations for TS-MCPs and duration of rotations can be optimized for the sustainment of trauma currency and competency.

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