PERFORMANCE ASSESSMENT

OF A MAJOR SCANDINAVIAN TRAUMA CENTER

DURING IMPLEMENTATION OF A DEDICATED TRAUMA SERVICE

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My interest in trauma started when I attended the "surgery of war" course in 2005, where I met Tina Gaarder and Pål Aksel Næss. The interest was further encouraged while working as a resident and trauma team leader at Oslo University Hospital - Ullevål (OUH-U) during the period 2006-2008. Through this work, the importance of a dedicated trauma infrastructure with robust trauma specific educational programs and multidisciplinary approach became obvious to me. It was a stimulating and instructive experience to be a part of the ongoing development of a dedicated Trauma Service.

At the end of my residency period I was offered the opportunity to engage in trauma research and evaluate aspects of the developing trauma system. This interesting and challenging project has resulted in three papers focusing on trauma center outcomes, and one paper reaching beyond the trauma center function.

Tina and Pål have been my mentors throughout the project, and my indispensable supporters. They have both an incomprehensive energy and enthusiasm, irrespective of time of the day. Tina is a wellspring of ideas and new approaches, with Pål as the eternal calming counterpart. Their outstanding guidance and inspiration have been crucial to me, and they deserve my gratitude.

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LIST OF PAPERS

The thesis is based on the following papers:

Paper 1:

Long-lasting performance improvement after formalization of a dedicated trauma service.

Groven S, Eken T, Skaga NO, Roise O, Naess PA, Gaarder C

J. Trauma. 2011. 70 (3):569-574

Paper 2:

Abdominal injuries in a major Scandinavian Trauma Center – performance assessment over an 8 year period.

Groven S, Gaarder T, Eken T, Skaga NO, Naess PA. Submitted.

Paper 3:

Effects of moving emergency trauma laparotomies from the ED to a dedicated OR.

Groven S, Naess PA, Skaga NO, Gaarder C

Scand.J.Trauma Resusc.Emerg.Med. 2013. 21:72-77

Paper 4:

A national survey on temporary and delayed abdominal closure in Norwegian hospitals.

Groven S. Naess PA, Trondsen E, Gaarder C

Scand.J.Trauma Resusc.Emerg.Med. 2011. 19:51-54

ABBREVIATIONS

OUH-U	Oslo University Hospital - Ullevål
ISS	Injury severity score
NOM	Non-operative management
ED	Emergency department
OR	Operating room
AIS	Abbreviated injury score
ASA-PS	American Society of Anestehsiologists Physical Status
GCS	Glascow coma scale
RTS	Revised trauma score
TRISS	Trauma score and injury severity score
VLAD	Variable life-adjusted display
CUSUM	Cumulative sum
Ps	Probability of survival
NTDB 05	National Trauma Data Bank 2005
AE	Angioembolization
ACS	Abdominal compartment syndrome
TAC	Temporary abdominal closure

BACKGROUND

Trauma remains a major cause of death and disability worldwide,[1, 2] and in western countries injury is the leading cause of death between ages 1 and 44.[3, 4] In Norway 47 per 100 000 persons under the age of 45 died of traumatic injuries in 2009, constituting near half of the deaths in this age group. [5] For every person who dies from injury another estimated 10 injured persons are hospitalized for specialized medical care.[6] An additional much larger number is visiting emergency departments for outpatient treatment of minor injuries. Trauma leads to loss of productivity and reduced quality of life for the injured who survive, as well as significant medical, psychosocial, and financial burden on the affected individuals and their families. Trauma care continues to be a significant public health concern.[6] In addition to preventive measures, there is a strong need for well-functioning systems for dedicated care of the injured through the whole treatment chain.

Trauma systems

Convincing evidence has demonstrated that organizing trauma care into regional trauma systems is effective and improves management and outcomes.[7-19] The term "trauma system" describes a dedicated and interconnected network including all aspects of patient care. The network extends from pre-hospital to in-hospital initial resuscitation with adequate predefined transfer guidelines to a higher level of care, including definitive care with rehabilitation, specific educational and performance improvement programs, and trauma-related research.[7, 20-22] This system requires dedicated resources, multidisciplinary team approach and extensive cooperation.

An absolute requirement for a regional trauma system is the dedicated trauma center with the necessary infrastructure to take the lead and responsibility for optimizing trauma care in the region. The trauma center should continuously work to develop and improve the system, focusing on the whole trauma system, not only in-hospital quality of care.

As described in American College of Surgeons Committee on Trauma´s ”Resources for the optimal care for the injured patient 2006”,[22] the goals of a trauma system are:

• To decrease the incidence and severity of trauma
• To ensure optimal care for all persons sustaining trauma
• To prevent unnecessary deaths and disabilities from trauma
• To contain costs while enhancing efficiency
• To implement quality and performance improvement of trauma care throughout the system
• To ensure certain designated facilities have appropriate resources to meet the needs of the injured

Trauma systems with mandatory trauma center verification programs are well developed in parts of the US. The American College of Surgeons trauma center verification program is based on the concept of a dedicated surgeon-led trauma service supported by a robust performance improvement program. In addition, all surgical specialties and necessary support functions must be available.[22] A trauma center requires a dedicated multidisciplinary trauma service consisting of physicians and support personnel engaged in the overall care of the patients. Most studies report improved survival for patients admitted to higher level centers and hospitals with dedicated trauma programs.[16, 23-27] However, only few studies have evaluated intra-institutional improvement of care as a consequence of instituting a formal trauma service in centers with all specialties and support functions already present. Without exception, the studies published demonstrate improvements in outcome, when comparing periods before and after the intervention.[25, 26, 28-30]
The ultimate quality indicator of trauma system implementation is a reduction in morbidity and mortality.[31, 32] Better outcomes can be accomplished through system planning and implementation of quality improvement programs.[33-36]

Status in Norway

Norway is a sparsely populated country with long transportation distances. At the start of this project, nearly fifty hospitals treated emergency surgical cases and admitted trauma patients.

Several hospitals admit less than one trauma patient per week,[37] and few hospitals reach a volume sufficient to generate enthusiasm and maintain competence in this complex field. Given the Norwegian geography and distribution of hospitals, every hospital providing acute care should ideally be able to provide initial care to a severely injured patient. This requires infrastructure and adequately educated staff, treatment protocols including all aspects of resuscitation, as well as predefined criteria for transfer to a higher level of care.
The description of a national trauma system "Traumesystem for Norge" was submitted to the national health authorities in 2007, stating the need for a national system, based on the existing health regions and with one major trauma center per region.[37] Since the formalization of the regional trauma centers, there is a growing political will to move forward in this field. Over the last couple of years the regional health authorities have decided to implement the plan for the national trauma system, and a National Trauma Competency Service has recently been instituted at Oslo University Hospital, with a mandate to oversee and quality ensure the implementation and maintenance of the national trauma system.

Oslo University Hospital - Ullevål (OUH-U)

OUH-U is the only hospital in Norway equivalent to a trauma center level I, the highest level of trauma centers in the US.[22] The institution serves as a referral center for more than half the Norwegian population, and is the regional trauma center for the South East Health Region, currently covering a population of 2.8 million. Of a total of more than 1600 trauma team activations per year (2012), consistently about 40% are severely injured with an Injury severity score (ISS) > 15.[31]
The OUH-U trauma care infrastructure has developed over time, starting in 1984 with a tiered trauma team, criteria for trauma team activation and an institutional trauma manual. The multidisciplinary trauma team has always been led by a surgical trauma team leader in cooperation with a consultant anesthesiologist. The infrastructure was developed and maintained by a few dedicated enthusiasts. Although the hospital provided all specialties and the full spectrum of clinical trauma care for many years, it did so in the absence of a formal trauma service.

With increasing surgical subspecialization, minimally invasive surgical techniques, work hour restrictions and more frequent non-operative management (NOM) of blunt trauma cases, the surgeons filling the role as surgical trauma team leaders have less general and trauma surgical experience. A review of the actual trauma operative experience for the team leaders in 2000-2002 confirmed obvious limitations to operative training in spite of the high volume of severely injured patients admitted.[38] An internal audit in 2003 showed multiple deviances from standards of care. In response, a number of changes were made over the next couple of years. In 2005, a dedicated trauma service was created, and a trauma medical director and a trauma coordinator were appointed. This led to the development of a clinical governance structure, a performance improvement framework, more formalized educational programs for physicians and nurses, followed by research infrastructure as well as the initiation of a regional trauma network (Figure 1).

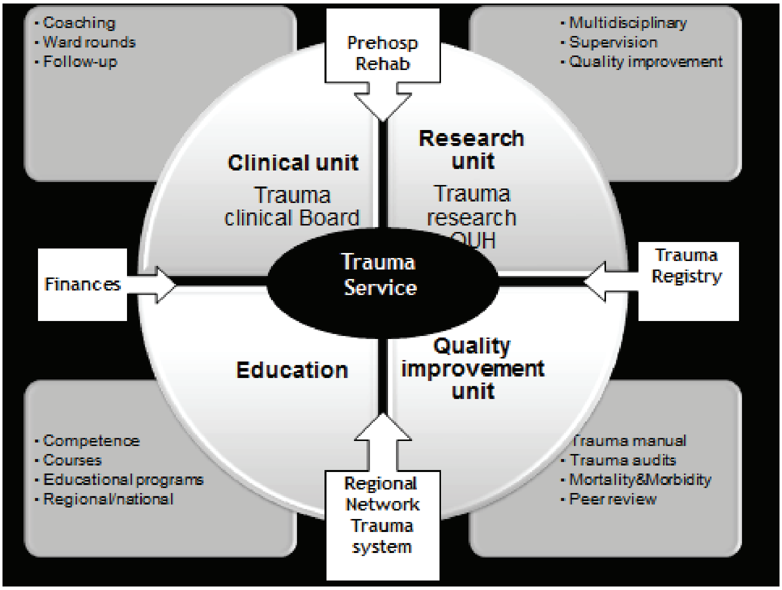

Figure1. The Trauma Service at OUH-U

Performance improvement

Better outcomes can be accomplished through trauma system planning and implementation of performance improvement programs.[11, 12, 14, 16] The term "performance improvement" in trauma describes the continuous evaluation through structured reviews of the process of care and outcomes.[34, 36, 39] Detailed planning is required for all components to interface successfully, enabling the system to work effectively. Continuous monitoring of the elements of diagnosis, treatment and outcome is essential. The performance of individual providers and the system in which they work must be evaluated to make sure optimal care is provided. The primary principle is to identify the problems arising due to correctable factors, and initiate corrective actions to ameliorate the problems (Figure 2). Finally the loop is closed by evaluating the effect of the changes to assess whether they have been successful in correcting the problem. Continuous revisions of plans, routines and protocols are necessary. Equally important are education, evidence-based research, and development and implementation of targeted injury prevention programs.

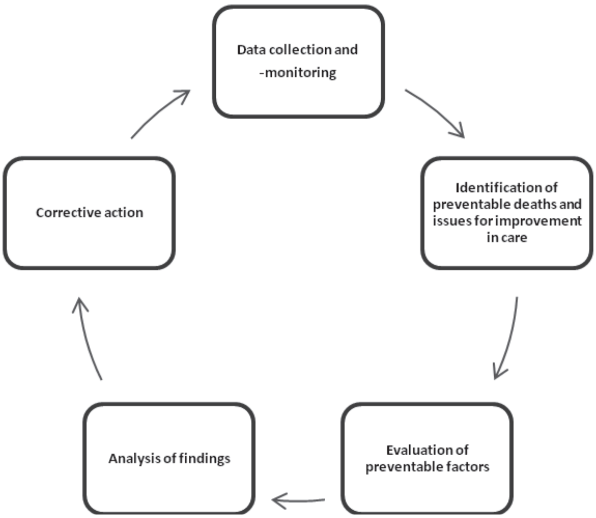

Figure 2. Perfomance improvement loop.

The factors affecting processes of care and outcome are however always multi-factorial. Researchers have with varying success tried to prove the importance of single factors.[32, 40-42] Several quality indicators like time frames are commonly used. Time to emergency laparotomy for hemodynamically unstable patients with abdominal injury has been used as process of care measure.[22, 39, 43-46] Shortening of time is considered beneficial, but has failed to prove the effectiveness or quality of the process.[32, 47]
A number of studies have compared outcome, focusing on mortality, morbidity, length of stay, as well as quality of life. Comparisons between different level centers most often show better outcomes for higher level centers.[8-10, 23, 24, 48] However, such comparisons require comparable populations and are difficult to interpret.[42] Evaluations of intra-institutional changes are necessary as part of a performance improvement program, and a tool to quantify the effect of changes in structure and organization.[39]

AIMS OF THE STUDY

In this project we wanted to investigate important elements of a trauma system with particular focus on the processes of care at OUH-U (Figure 3). Our first aim was to explore the total trauma population in search of changes in outcome and factors affecting quality of care (paper 1). Papers 2 and 3 focus on specific subpopulations of patients. OUH-U is the lead agency in the South Eastern regional trauma system and has to a certain extent also national functions. It was therefore equally important to extend the work beyond the trauma center. The last paper (paper 4) is exploring a defined patient category and treatment line within the regional trauma system and nationally, aiming at describing one condition that could benefit from improved inter-institutional cooperation.

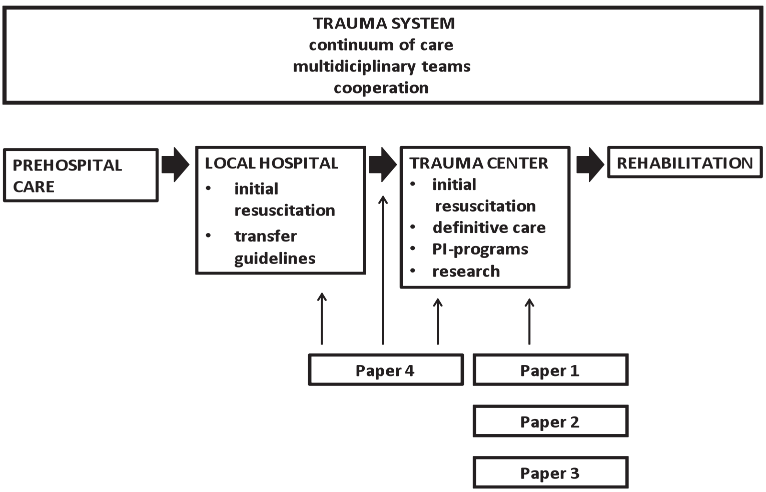

Figure 3. Each individual paper's point of focus in the trauma system

Research questions:

- Possible effects of the described structural changes on outcome in the trauma population at OUH-U: Would the institution of a dedicated trauma service with increased multidisciplinary focus on trauma care be accompanied by increased survival? And would it be possible to identify a specific point in time for change in performance?

- We subsequently wanted to explore the effect of increasing NOM on the number of trauma laparotomies and thus surgical experience with major abdominal procedures. A general assessment of abdominal injury outcome would reveal changes in mortality, missed injuries and non-therapeutic laparotomies.

-In hemodynamically compromised patients, laparotomy used to be performed in a fully equipped emergency department (ED). This routine was changed gradually in 2006 towards moving most patients to a dedicated operating room (OR). We wanted to evaluate impact on time, number of futile and non-therapeutic procedures as well as mortality.

-We performed a national survey to estimate the number of patients with abdominal compartment syndrome and temporary abdominal closure, hypothesizing that the frequency of such patients in most hospitals was low, with a potential benefit from increased inter-institutional cooperation.

MATERIALS AND METHODS

Paper 1 is a retrospective analysis of all trauma patients included in the institutional trauma registry (Trauma Registry Ullevål) during the 7-year period from January 2002 to December 2008.

Paper 2 is a retrospective analysis of all trauma patients with abdominal and/or diaphragmatic injury with Abbreviated injury score (AIS) >1 included in the trauma registry during the 8-year period from January 2002 to December 2009. We then analyzed data for the 459 consecutive patients undergoing laparotomy.

Paper 3 is an analysis of 167 hemodynamically compromised patients of the 459 patients in paper 2.

Data for the first 3 papers were retrieved from the trauma registry and through direct review of patient charts. The trauma registry includes all trauma patients admitted through trauma team activation (irrespective of ISS), or with penetrating injuries proximal to elbow or knee, or with ISS ≥ 10 admitted to OUH-U directly or via a local hospital within 24 hours after injury. Transfers more than 24 hours after injury are included only if the trauma team is activated.

Data extracted included demographics, pre-injury physical status according to the American Society of Anesthesiologists Physical Status (ASA-PS) classification system,[49, 50] mechanism of injury, ISS, Glasgow coma scale (GCS) score, revised trauma score (RTS), 30-day survival, and main cause of death. Anatomic injury was classified according to the Abbreviated Injury Scale 1998 (AIS-98).[51]

In paper 4 we performed a national survey. A questionnaire was in 2009 sent to one attending surgeon in every general/gastrointestinal surgical department in all 50 Norwegian hospitals with acute care surgical facilities. A follow-up internet-based questionnaire was sent to the same surgeons one year after the initial survey. Questionnaires were coded to maintain confidentiality. The survey fulfilled the criteria for an observational study since we collected information of interest without influencing the treatment.

Statistics

For papers 1, 2 and 3 the primary outcome parameter was mortality. For paper 2, the number of laparotomies, rate of non-therapeutic laparotomies and rate of missed injuries were reviewed as secondary outcome parameters. For paper 3 rates of futile and non-therapeutic laparotomies as well as time to surgery were reviewed.

Chi square and Fisher's Exact tests were used for analyses of categorical data, and Student's t test and Mann-Whitney U test were used for normally and non-normally distributed non-categorical data, respectively.

For paper 1, statistical analyses were performed using StatView 6.5 statistical software (SAS Institute Inc.). For papers 2 and 3, statistical analyses were performed using PASW Statistics 18 statistical software (SPSS Inc.). A p value of < 0.05 was considered to indicate significance for all three papers.

W-statistics is expressing excess survivors per 100 patients treated compared to Trauma score and injury severity score (TRISS) model predictions according to the following equation.

$$W = \frac{\text{actual number of survivors} - \text{predicted number of survivors}}{\text{number of patients }/100}$$

W-statistics was calculated according to convention and used to estimate outcomes in all three studies.[52] Non-overlapping 95% confidence intervals were deemed as significant differences between groups.

Variable life-adjusted display (VLAD) was used in paper 1 and 2 in order to describe risk-adjusted survival trends, and to detect a possible time point for change in survival. VLAD is a refinement of the cumulative sum (CUSUM) method that adjusts death and survival by each patient's risk status, probability of survival (Ps), and provides a graphical display of performance over time.[53] Ps was calculated using TRISS methodology with National Trauma Data Bank 2005 (NTDB 05) coefficients. Every patient was assigned a value corresponding to gained or lost fractional life. Each survivor contributed a reward of 1-Ps, and each death a penalty of -Ps. The cumulative sum of penalties and rewards showed the difference between expected and actual cumulative mortality over time. Downward deflection of the VLAD graph indicated suboptimal trauma care compared to benchmark, while upward deflection suggested better outcome than benchmark and improved standards of care if the deflection occurred compared to a previous period in the same institution. Since the population used as benchmark does not represent a comparable population, it should be obvious that VLAD only allows for intra-institutional evaluation over time.

SUMMARY OF THE INCLUDED PAPERS

Paper 1:

In 2005 a dedicated trauma service was instituted at OUH-U, and we wanted to evaluate the impact of structural changes on outcome, hypothesizing that increased multidisciplinary focus on trauma care would be accompanied by increased survival. Additionally, VLAD was used to see changes in outcome and performance as they occurred over time.

The study is a retrospective analysis of 7247 trauma patients entered in the institutional trauma registry during the 7-year period from January 2002 to December 2008.

A sharp increase in cumulative survival starting at the beginning of 2005 and with a steady performance throughout the study period was demonstrated by VLAD, amounting to a total of 68 additional saved lives for the whole study period compared to benchmark. As expected, the increase was mainly caused by improved survival among the critically injured (ISS 25–75). A cutoff point t_0 for analysis of differences between time periods was set at 01.01.2005, coinciding with the formalization of a dedicated trauma service. The period before and after the formalization of the dedicated trauma service were compared for demographics and 30-day crude and adjusted mortality. Unadjusted mortality in the whole trauma population showed a 33 % decrease after t_0, and W statistics confirmed the increased survival to be significant.

The study is to our knowledge the first to show that the start of a long-lasting performance improvement coincided with formalization of a dedicated trauma service providing increased multidisciplinary focus on all aspects of trauma care.

Paper 2:

The decreasing laparotomy rate expected to follow increasing NOM and the use of angioembolization (AE) in the treatment of solid organ injuries combined with work hour restrictions and increasing subspecialization creates new educational and system development challenges.

In order to assess performance for the subgroup of patients with abdominal injuries, a total of 955 patients admitted over the period 2002 to 2009 were analyzed. Based on the results from Paper 1, 01.01.2005 was chosen as cutoff for comparison between the two time periods. Like in Paper 1, VLAD was used to assess performance over time. Most changes affecting the management of abdominal injuries specifically had been implemented during the early 2000s. Therefore, we did not expect to find the change in performance in 2005 identified in Paper 1 for this subpopulation.

VLAD demonstrated a stable performance during the study period. Adjusted mortality rates did not differ between the periods. The number of laparotomies remained unchanged in spite of an increasing number of patients with abdominal injuries. The average number of trauma laparotomies each surgical trauma team leader was involved in per year was eight.

The study demonstrated that the experience with abdominal injuries and trauma laparotomies offered surgeons in training in a European high volume trauma center remain limited.

Paper 3:

Hemodynamically compromised trauma patients with intra-abdominal bleeding are challenging, and require immediate attention from a multidisciplinary team with hemorrhage control as the main goal. Time aspects, the team experience and ability to cooperate and communicate, resuscitation routines and operating room facilities and equipment may affect outcome.
Until 2006, the institutional protocol allowed trauma laparotomies routinely to be performed in the fully equipped trauma room in the ED. However, the current trauma room is not a formal operating room, and in spite of the risk of increasing time to laparotomy, patients in need of laparotomy were from 2006 increasingly transferred to a dedicated OR one floor above the ED.
We wanted to quantify the reduction in ED laparotomies over time. We set out to analyze whether the change had affected mortality, time to laparotomy, and the number of futile and non-therapeutic laparotomies.
Of the 459 patients undergoing laparotomy in Paper 2, 192 were deemed unstable on arrival in the ED. Patients undergoing futile laparotomies were excluded, leaving 167 patients to constitute the study population. Based on time for protocol change, January 2007 was chosen as a cutoff point between Period 1 and 2.
The ED laparotomy rate was significantly reduced in period 2, while the rate of non-therapeutic laparotomies remained unchanged. Median time to laparotomy increased, but there was no concomitant increase in mortality rates.

Paper 4:

Damage control techniques for trauma as well as prevention and treatment of abdominal compartment syndrome (ACS) includes the use of temporary abdominal closure (TAC). All TAC techniques are associated with a range of complications and follow-up of patients with an open abdomen demands multidisciplinary teamwork and experience with complex reconstructions. Patients with ACS or TAC are therefore on the list of criteria for transfer to a regional trauma center. We wanted to quantify the exposure of Norwegian hospitals to TAC after trauma laparotomies and ACS regardless of cause. We hypothesized that the experience would be limited and that this subgroup of patients might benefit from increased centralization as part of the implementation of regional trauma systems.
We performed a national survey. A questionnaire was in 2009 sent to one attending surgeon in all 50 Norwegian hospitals with acute care surgical facilities. A follow-up internet-based questionnaire was sent to the same surgeons one year after the initial survey.
We achieved a response rate of 88%. A very limited number of hospitals had treated more than one trauma patient with TAC (5%) or one patient with ACS (14%) on average per year. Most hospitals preferred vacuum assisted techniques, but few reported having formal protocols for TAC or ACS. Although most hospitals would refer patients with TAC to a regional trauma center, more than 50 % reported that they would perform a secondary reconstruction procedure themselves.
After initial treatment, these patients might benefit from referral to a regional center for further care.

DISCUSSION

Trauma systems

Injury is a significant source of premature mortality, hospitalizations, and health care expenditure in Norway.[5] The implementation of inclusive regional trauma systems integrating the whole treatment chain has been shown to be effective in reducing disability and patient mortality by up to 20%.[9, 11, 15, 54, 55] Continued improvements are possible in an established system if adequately and continuously audited and monitored.[33, 36, 56] Appropriate use of the trauma system is fundamental to providing a consistent systematic approach to trauma care.[16, 56]

The goal of a trauma system is to facilitate treatment of severely injured patients at a hospital with the required resources.[10, 54, 57] Care at a designated trauma center is associated with a significant reduction in mortality after severe injury when compared with care at a non-trauma center.[23, 27, 58] Trauma centers recruit relevant competence and organize resources to optimize care for the injured patient. Concentrating the severely injured patients at these centers ensures volume to maintain service and clinical competence.

Demetriades et al. stated that human and economic resources dedicated to trauma programs is a sound investment,[16] and there are several reasons to believe this holds true also in the Norwegian context. However, although the literature supporting regional trauma systems with trauma centers as the ultimate address for severely injured patients is robust,[9, 11, 14, 15, 23] experience from one institution or a health care system cannot automatically be translated to another.[23, 59] In Norway, the regional trauma system is in its implementation phase.[37] OUH-U is the only equivalent to a level I trauma center, with a dedicated trauma service implemented in 2005, adding robust multidisciplinary patient follow-up, educational, research and quality improvement programs to the existing trauma care infrastructure.

Taking on the formal responsibility for optimizing trauma care in the region covering more than half the Norwegian population, a thorough overall performance assessment was deemed necessary and was initiated as the start of this project. We then aimed at analyzing one specific subgroup of patients challenging the trauma center multidisciplinary function by virtue of their complexity, namely the patients with abdominal injuries. The third study aimed at assessing the effect of a specific protocol change affecting the same subgroup. To focus on the regional function, study 4 identified ACS and TAC as clinical conditions that might benefit from cooperation and, potentially, centralization of treatment.[60-67]

Methodological aspects

Like others,[25, 26, 28-30] we were able to demonstrate a significant improvement in survival after instituting a formal trauma service (Paper1). To our knowledge, we are the first to use VLAD as a tool to demonstrate and define the exact time for a change in overall performance for a trauma center. The abrupt improvement identified occurred at the same time as the implementation of the formal trauma service, early in 2005, and remained stable throughout the study period. Furthermore, our significantly increased survival was based on adjusted survival rates, correcting for patient physiology and injury grade, compared to publications based on crude mortality rates.[26, 29]

Although not uncommonly performed, a comparison with other institutions seemed irrelevant to us due to differences in set-up, registry routines and patient populations.[35, 42, 68, 69] Also, due to the lack of other high volume institutional trauma registries in Norway, a comparison would only be relevant with centers outside the country, increasing the potential population differences. As a self-assessment, comparing consecutive periods makes sense, although weakened by the historic control aspect, allowing for confounding factors. In addition, an overall performance improvement is likely multi-factorial, with changes made over the study period influencing outcome. We had an increase in admitted patients, reported in some studies to be associated with increased survival,[70, 71] while others found no relationship.[72, 73] A steady increase in admitted patients could however not explain the distinct increase in survival that subsequently remained stable. Exploring all institutional changes over the study period, we were unable to identify any single factor other than the trauma service implementation that could explain the improved performance (Paper 1).

VLAD incorporates information on outcome and estimated risks for each individual case, allowing early identification of variations in clinical outcome that are not easily detected by evaluations of average performance in longer time periods.[53, 74, 75] In Paper 1, VLAD allowed us to identify a specific point in time for a substantial performance improvement. VLAD is a useful tool for continuous performance assessment because of its ability to detect both positive and negative changes in performance trends at an early stage. However, deficiencies in trauma care not leading to death will escape detection.

Most institutional changes affecting abdominal injuries and general trauma surgical practice had been instituted several years before the formalization of the trauma service. This included robust educational programs, formal protocols for NOM with AE in liver and spleen injuries, and protocols for ACS and TAC.[76-78] Setting out to assess the subpopulation with abdominal injuries and those undergoing laparotomy over the period 2002-2009, we were hoping for a stable performance, not declining due to high turnover rates of surgical trauma team leaders, less surgical experience overall, increasing sub-specialization, and limited trauma surgical exposure with increasing NOM rates and more frequent use of AE.[79-85]

In Paper 2, VLAD did confirm a stable performance over the entire study period, in accordance with a non-significant increase in adjusted survival rates. The observed significant decrease in crude mortality rates does however call for cautious use of crude mortality rates in trauma research.[42, 52, 69, 86]

Trauma surgical experience

The increase in patients with abdominal injuries was accompanied by a stable number of laparotomies per year. Surgical trauma team leader exposure to trauma laparotomies remained unchanged, for an average of 8 cases per year. In many countries low volumes of trauma cases and limited exposure to trauma laparotomies combined with increasing subspecialization constitute a threat to trauma education and competence.[79-83, 87-89] The stable performance in Paper 2 was accompanied by the unchanged number of laparotomies, a decreased number of NOM failures, and without increase in missed injuries, non-therapeutic laparotomies or mortality. With high turnover and limited trauma surgical experience of the trauma team leaders, this could only have been achieved with the robust institutional trauma surgical educational program and continuous follow-up by the dedicated trauma service. The results call for a formal trauma consultant on call service, in order to maintain quality of care and counteract the development in surgical education.

Quality indicators – how useful are they in trauma?

It is essential to measure the quality of care with reliable and valid tools, and the ultimate quality indicator in trauma care is survival. Effect on mortality is often difficult to measure in this complex patient population, and other outcome measures like time to diagnosis and treatment, failure of NOM, missed injury rates and non-therapeutic and futile laparotomy rates are commonly used quality indicators. However, existing literature fails to prove their value as more than substitutes,[32, 40-42, 47, 90-93] and only a few quality indicators demonstrate evidence to warrant further use. Stelfox et al [40, 47] performed a systematic review of the literature in 2010. Of 6869 abstracts 192 full-text articles were included in this review. The main result was lack of clearly defined and evidence-based quality indicators. The results of our studies should therefore, like others, be interpreted with caution until further evidence can be presented.

A specific change made to the abdominal injury population during the study period, was the transition from performing trauma laparotomies in hemodynamically compromised patients in the ED trauma room to a dedicated OR. The change was made due to the fact that the trauma room is not a formal OR, although fully equipped for major surgical procedures, and also due to a significant number of futile laparotomies performed in the ED. Time to laparotomy has been presented as a quality indicator,[22, 32, 39, 43, 47] and we were aware of the potential for increasing the time to surgery, and the need for a subsequent evaluation of the effect of this change.

We analyzed the subpopulation of 167 hemodynamically compromised patients from Paper 2, comparing the period before and after gradual transition from ED to OR laparotomy in 2006. The change virtually eliminated futile laparotomies and reduced the number of non-therapeutic laparotomies. Median time to laparotomy increased, this did however not lead to a concomitant increase in mortality (Paper 3).

With support from the existing literature, screaming for evidence to support any of the accepted and frequently used audit filters,[32, 40-42, 47, 90-93] our study results seem to challenge time to laparotomy as a valid audit filter in this specific population. The protocol remains unchanged, although we will be aiming at moving the dedicated OR closer to the trauma room, since it is beyond discussion that time is of the essence in the critically injured bleeding trauma patient.

Beyond the trauma center

The regional trauma system led and supported by the trauma center should assess and strive to optimize all aspects of trauma care, from the scene of injury to rehabilitation. Paper 4 presents a survey confirming the infrequent occurrence in most hospitals of certain specific clinical conditions beyond the initial resuscitative phase, calling for increased cooperation, coordination and potentially centralization of treatment.

Norway has a challenging geography with long distances and large areas with sparse population. The four health regions have different challenges. Efforts are needed to coordinate the different regional trauma systems into a national trauma system in order to optimize trauma care. This should also include developing national guidelines minimize the vulnerability caused by low volumes and lack of experience as shown in Paper 4. The recently launched Norwegian Trauma Competency Service (Nasjonal Kompetansetjeneste for traumatologi), organizationally located under the trauma service at OUH-U, with representation from all four health regions, has the potential to achieve this common goal.

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I

II

Title: Abdominal injuries in a major Scandinavian Trauma Center – performance assessment over an 8 year period.

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Abstract

Introduction: Damage control surgery and damage control resuscitation have reduced mortality in patients with severe abdominal injuries. The shift towards non-operative management in haemodynamically stable patients suffering blunt abdominal trauma has further contributed to the improved results. However, in many countries, low volume of trauma cases and limited exposure to trauma laparotomies constitute a threat to trauma competence. The aim of this study was to evaluate the institutional patient volume and performance for patients with abdominal injuries over an eight-year period.

Methods: Data from 955 consecutive trauma patients admitted in Oslo University Hospital Ulleval with abdominal injuries during the eight-year period 2002-2009 were retrospectively explored. A separate analysis was performed on all trauma patients undergoing laparotomy during the same period, whether abdominal injuries were identified or not. Variable life-adjusted display (VLAD) was used in order to describe risk-adjusted survival trends throughout the period and the patients admitted before (Period 1) and after (Period 2) the institution of a formal Trauma Service (2005) were compared.

Results: There was a steady increase in admitted patients with abdominal injuries, while the number of patients undergoing laparotomy was constant exposing the surgical trauma team leaders to an average of 8 trauma laparotomies per year. No increase in missed injuries or failures of non-operative management was detected. Unadjusted mortality rates decreased from period 1 to period 2 for all patients with abdominal injuries as well as for the patients undergoing laparotomy. However, this apparent decrease was not confirmed as significant in TRISS-based analysis of risk-adjusted mortality. VLAD demonstrated a steady performance throughout the study period.

Conclusion: Even in a high volume trauma center the exposure to abdominal injuries and trauma laparotomies is limited. Due to increasing NOM, an increasing number of patients with abdominal injuries was not accompanied by an increase in number of laparotomies. However, we have demonstrated a stable performance throughout the study period as visualized by VLAD without an increase in missed injuries or failures of NOM.

Keywords:

Trauma; abdominal injury; laparotomy; non-operative management; performance improvement; variable life-adjusted display; survival.

Introduction

Damage control surgery and damage control resuscitation have reduced mortality in patients with severe abdominal injuries [1;2]. The shift towards non-operative management (NOM) in haemodynamically stable patients suffering blunt abdominal trauma has further contributed to the improved results [3-6]. However, in many countries low volumes of trauma cases and limited exposure to trauma laparotomies combined with increasing subspecialization constitute a threat to education and competence with this patient group [7-14].

The above description seems applicable to Norway as well, where Oslo University Hospital Ulleval (OUH-U) is the only equivalent to a Level I trauma centre. In 2000-2002, based on the existing trauma centre infrastructure, protocols were revised and educational programs improved. Moreover, new treatment protocols for abdominal compartment syndrome, temporary abdominal closure and solid abdominal injuries including angiographic embolization were introduced, the latter leading to increased NOM rates [15;16]. During the same period, our surgical trauma team leaders participated in no more than 10 trauma laparotomies annually despite a high percentage of severely injured patients admitted [17].

This study was undertaken to assess the institutional patient volume and performance over the period 2002-2009 for patients with abdominal injuries including the use of variable life-adjusted display (VLAD) in order to describe risk-adjusted survival trends throughout the period. Since we recently demonstrated that the start of a long-lasting performance improvement with increased survival coincided with the formalization of a dedicated Trauma Service in 2005 [18], we chose to compare the periods before and after the institution of this Service in order to analyze commonly used indicators of negative performance.

Patients and methods

OUH-U is a major Scandinavian trauma centre admitting approximately 1 500 trauma patients per year. It serves as a regional trauma centre for 2.7 million people, more than half the Norwegian population. Blunt trauma is the mechanism of injury in 90% of the patients. Consistently, approximately 40% (500-600 patients per year) [18] are severely injured with an injury severity score (ISS) >15 [19].

The current study is a retrospective analysis of all patients in the OUH-U trauma registry admitted from January 1, 2002 to December 31, 2009 with abdominal or diaphragmatic injury grade ≥ 2 according to the Abbreviated Injury Scale 1990 Revision, update 98 (AIS 98) [20]. In order to assess surgeons' exposure to operative trauma care, a separate analysis was performed on a population consisting of all trauma patients undergoing laparotomy during the same period, whether abdominal injury was identified or not. Based on a recently published study from our institution in which we demonstrated increased survival from 2005 for the total trauma population [18], we chose to compare the period before (period 1; 2002 to 2004) and after that time point (period 2, 2005 to 2009).

Patients were identified from the OUH-U Trauma Registry and data extracted included age, gender, mechanism of injury, ISS, Glasgow coma scale (GCS) score, surgical procedure codes, probability of survival (Ps) calculated using TRISS methodology [19] with National Trauma Data Bank 2005 (NTDB 05) coefficients, hospital length of stay (LOS), 30-day survival [21], and main cause of death. The OUH-U Trauma Registry, which has been operational since August 2000, includes all trauma patients admitted through trauma team activation (irrespective of ISS), or with penetrating injuries proximal to elbow or knee, or with head injury AIS ≥ 3, or with ISS ≥ 10 admitted to OUH-U directly or via a local hospital within 24 hours after injury. Patients with an isolated single extremity fracture and transfers more than 24 hours after injury are included only if the trauma team is activated. In cases where patients were intubated and anaesthetized before admission, GCS score and respiratory rate were recorded as the values documented immediately prior to intubation. For the population undergoing laparotomy, patient charts were used to extract data on surgical procedures, failure of NOM, missed injuries and non-therapeutic laparotomies. Patients undergoing laparotomy before transfer to OUH-U were excluded from this analysis. Failure of NOM was defined as any laparotomy in patients where the intention after initial work-up had been that of NOM. Missed injury was defined as an injury not recognized at the completion of the initial work-up and treatment, but later leading to a therapeutic procedure. A laparotomy was deemed non-therapeutic by the absence of intra-abdominal injury necessitating surgical intervention. In cases of doubt regarding categorization of laparotomies, the three authors with surgical competence reached consensus.

Data analysis

Period 1 and period 2 were compared for demographics and 30-day mortality, first for the total population with diagnosed abdominal injuries with AIS ≥ 2, and subsequently for the population of patients undergoing laparotomy.

VLAD was used in order to describe risk-adjusted survival trends throughout the eight-year period. VLAD is a refinement of the cumulative sum method that adjusts death and survival by each patient's risk status (probability of survival, Ps), providing a graphical display of performance over time [22]. Every patient was assigned a value corresponding to gained or lost fractional life. Each survivor contributed a reward of 1 – Ps and each death a penalty of – Ps. Starting from zero, each patient's contribution in terms of reward or penalty was added to the summed contribution of all previous patients and the resulting number plotted vs. time of patient admission. This plot of cumulative sum of penalties and rewards shows the difference between expected and actual cumulative mortality over time, i.e., the number of excess saved lives compared to the reference model (TRISS with NTDB 2005 coefficients) since the first patient was admitted. A linear VLAD graph thus indicates stable performance while an upward deflection suggests improved standards of care and a downward deflection indicates a decline in performance. Consequently, the relation to the chosen reference model is less interesting than changes in trend over time in the studied population [22].

W-statistics, expressing excess survivors per 100 patients treated at OUH-U compared to TRISS model prediction, was calculated according to convention and used to compare outcomes for the two periods [23]. Non-overlapping 95% confidence intervals were deemed as significant differences between groups.

Fisher's Exact tests was used for analyses of categorical data, and Student's t test and Mann-Whitney U test were used for normally and non-normally distributed continuous data, respectively.

Statistical analyses were performed using PASW Statistics 18 statistical software (SPSS Inc., Chicago, USA) and StatView 6.5 statistical software (SAS Institute, Inc., Cary, USA). A p value of < 0.05 was considered to indicate significance.

The study was approved by the Institutional Data Protection Officer, and the Regional Committee for Medical Research Ethics had no objections.

Results

A total of 955 patients with abdominal injury AIS grade ≥ 2 were identified, 325 patients in period 1 and 630 patients in period 2. Demographics are shown in Table 1. A total of 459 trauma patients were identified to have undergone laparotomy, 163 patients in period 1 and

296 patients in period 2 (Table 2). The high ISS and mortality rates reflect that many of these patients were polytraumatized with severe extraabdominal injuries.

In spite of an increase in admitted patients with abdominal injuries in period 2, the annual number of patients undergoing laparotomy was remarkably stable throughout the study period (Figure 1). With one night in seven on call the trauma team leaders participated in an average of 8 trauma related laparotomies per year.

Unadjusted mortality rates decreased from period 1 to period 2 for all patients with abdominal injuries and for the population undergoing laparotomy, and was accompanied by an increase in LOS in both groups (Table 1 and Table 2). However, an increase in GCS score and a decrease in ISS could be detected between the periods, indicative of a less injured patient population in period 2. The significant increase in survivors from period 1 to period 2 was not accompanied by a corresponding reduction in risk-adjusted mortality (W-statistics), as demonstrated by overlapping confidence intervals (Tables 1 and 2). In accordance with this, VLAD demonstrated a steady performance throughout the study period (Figure 2).

Main causes of death for patients undergoing laparotomy are listed in Table 3, showing bleeding as the main cause of death in both periods, followed by head injury and sepsis/MOF.

There was a significant reduction in failure of NOM and a trend toward decreasing non-therapeutic laparotomies and missed injuries in period 2 (Table 4). Approximately half of the patients that underwent non-therapeutic laparotomies in both periods (26/51 in period 1 and 38/80 in period 2; p=0.72) had sustained penetrating trauma.

Discussion

The present report demonstrates a limited exposure to abdominal injuries and trauma laparotomies in our hospital. One could fear that such a low exposure, now largely depicted as part of the "future of trauma", might jeopardize education and clinical competence and result in deteriorating performance [8;11;24-26]. However, a stable performance over the study period for patients with abdominal injuries was demonstrated by VLAD. The increase in patient volume was not accompanied by an increase in the number of laparotomies. However, there was no increase in missed injuries or failures of NOM.

In 2000-2002, based on the existing trauma centre infrastructure, protocols were revised and educational programs improved. Moreover, new treatment protocols for abdominal compartment syndrome, temporary abdominal closure and solid abdominal injuries including angiographic embolization were introduced, the latter leading to increased NOM rates [15;16]. In a recently published study using VLAD on all trauma patients entered in the institutional trauma registry during the period 2002-2008 we demonstrated that the start of a long-lasting performance improvement with increased survival coincided with the formalization of a dedicated trauma service in 2005 [18]. The absence of a similar distinct change in performance for the subpopulation with abdominal injuries is likely caused by the above mentioned fact that most changes in protocols and education affecting the treatment of abdominal injuries specifically occurred before 2002. The reduction in crude mortality was accompanied by an increase in LOS. In addition to fewer deaths causing very short LOS, this change is most likely caused by a 5 bed increase in surgical ICU capacity over the study period. Patients previously transferred to their local hospital at an earlier stage could be kept in the trauma center when deemed beneficial in order to optimize care. NOM for blunt trauma might lead to delayed diagnosis and treatment of hollow viscus injury, and such delays have been associated with increased mortality [27-30]. In spite of the high NOM rate in our material, the rate of missed injuries remained low throughout the study period.

Our protocol mandated immediate laparotomy in haemodynamically compromised patients with verified or suspected ongoing abdominal bleeding or patients with peritonitis. Patients with suspected or verified hollow organ injury or diaphragmatic disruption based on radiological findings underwent laparotomy. A significant number of laparotomies performed in both periods were non-therapeutic (Table 4). This may be explained by the finding in both periods that half of these patients had sustained penetrating trauma. It was only in 2007 that a protocol allowing observation of haemodynamically stable patients with abdominal stab wounds was implemented. Thus, an effect on the non-therapeutic laparotomy rate is not expected to be visible in the current study.

Some weaknesses should be commented on in addition to those associated with the retrospective nature of the study and the use of historical controls. Differences in case mix and changes in patient volume are factors that could influence outcome independent of institutional performance. However, such differences are adjusted for in the survival prediction model. The categorization of laparotomies as being therapeutic or not, injuries as being missed, and failures of NOM are subject to some degree of subjectivity. However, the same commonly used definitions were applied in both periods, and in cases of doubt, the three authors with surgical competence reached consensus.

A VLAD chart has some weaknesses calling for cautious interpretation. The method is dependent on the rate of data collection, e.g., the slope of the curve representing excess survivors over time will increase if more patients are included per time unit even when performance is unchanged, provided that it is better than the underlying survival prediction model. However, when plotted against patient numbers instead of time, the visual impression remains the same for our patient population. Furthermore, any short-term change can be due to random error. Additionally, as for any survival analysis, deficiencies in trauma care not leading to death will escape detection. However, the obvious benefit of VLAD is its ability to detect both positive and negative changes in clinical performance at an early stage and we recommend VLAD as a valuable instrument for trauma auditing purposes that should be more widely used.

Even in a high volume trauma center the exposure to abdominal injuries and trauma laparotomies is limited. Due to increasing NOM, an increasing number of patients with abdominal injuries was not accompanied by an increase in number of laparotomies. However, we have demonstrated a stable performance throughout the study period as visualized by VLAD without an increase in missed injuries or failures of NOM.

Competing interest: The authors declare that they have no competing interests.

Authors´contributions: SG: Study design, collected and extracted data, performed statistical analysis, generated illustrations, drafted the manuscript and interpreted the data, co-wrote and critically reviewed the manuscript. CG: Study design, drafted the manuscript and interpreted the data, co-wrote and critically reviewed the manuscript. TE: Performed the VLAD analyses, revised all statistics, co-wrote and critically reviewed the manuscript. NOS: Extracted data from the OUH Trauma Registry, performed the W-statistics analyses, co-wrote and critically reviewed the manuscript. PAN: Study design, drafted the manuscript and interpreted the data, co-wrote and critically reviewed the manuscript. All authors have read and approved the final manuscript.

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Table 1 Comparison of Period 1 and 2 for patients with abdominal injury

	Period 1 n=325	**Period 2 n=630**	***p***
Age, mean	34.6	33.4	0.36
Male (%)	243 (75)	453 (72)	0.36
Blunt (%)	281 (86)	542 (86)	0.92
GCS score, median (quartiles)	15.0 (7.5-15.0)	15.0 (11.8-15.0)	<0.01
ISS, median (quartiles)	29.0 (17.0-42.0)	26.0 (16.0-38.0)	0.05
LOS, median (quartiles)	6.0 (3.0-11.0)	8.0 (4.0-14.0)	<0.01
Deaths (%)	63 (20)	65 (10)	<0.01
W NTDB 05 (95% CI)	4.14 (1.93 to 6.36)	6.77 (4.83 to 8.71)	

GCS: Glasgow Coma Scale; ISS: injury severity score; LOS: length of stay; W NTDB 05: W-statistics with coefficients from National Trauma Data Bank 2005; CI: confidence interval.
One patient from period 2 has missing data on age, mechanism of injury, GCS and ISS.

Table 2 Comparison of Period 1 and 2 for patients undergoing laparotomy

	Period 1 n=163	**Period 2 n=296**	***p***
Age, mean	37.4	36.6	0.63
Male (%)	127 (78)	220 (74)	0.42
Blunt (%)	99 (61)	183 (62)	0.84
GCS score, median (quartiles)	15.0 (5.0-15.0)	15.0 (9.0-15.0)	0.09
ISS, median (quartiles)	29.0 (10.0-45.0)	25.0 (10.0-38.0)	0.02
LOS, median (quartiles)	5.0 (2.0-11.0)	8.0 (3.0-16.0)	<0.01
Deaths (%)	60 (37)	59 (20)	<0.01
W NTDB 05 (95% CI)	0.25 (-3.81 to 4.30)	3.91 (0.99 to 6.84)	

GCS: Glasgow Coma Scale; ISS: injury severity score; LOS: length of stay; W NTDB 05: W-statistics with coefficients from National Trauma Data Bank 2005; CI: confidence interval.
One patient from period 2 has missing data on age, mechanism of injury, GCS and ISS.

Table 3 Main causes of death for patients undergoing laparotomy

	Period 1		Period 2		
	N	**%**	**N**	**%**	***p****
Bleeding	36	60	37	63	0.85
Sepsis/MOF	7	12	6	10	1.00
Head injury	11	18	8	13.5	0.62
Other/unknown	6	10	8	13.5	0.58
Total	60	100	59	100	

MOF: multiple organ failure
*Fisher's Exact tests for each individual cause against the sum of all other causes

Table 4 Missed injuries, NOM failures and non-therapeutic laparotomies

	Period 1 n= 163	**Period 2 n= 296**	***p***
Missed injuries (%)	9 (6)	13 (4)	0.65
Failure of NOM (%)	9 (6)	5 (2)	0.04
Non-therapeutic laparotomies (%)	51 (31)	80 (27)	0.33

NOM: non-operative management

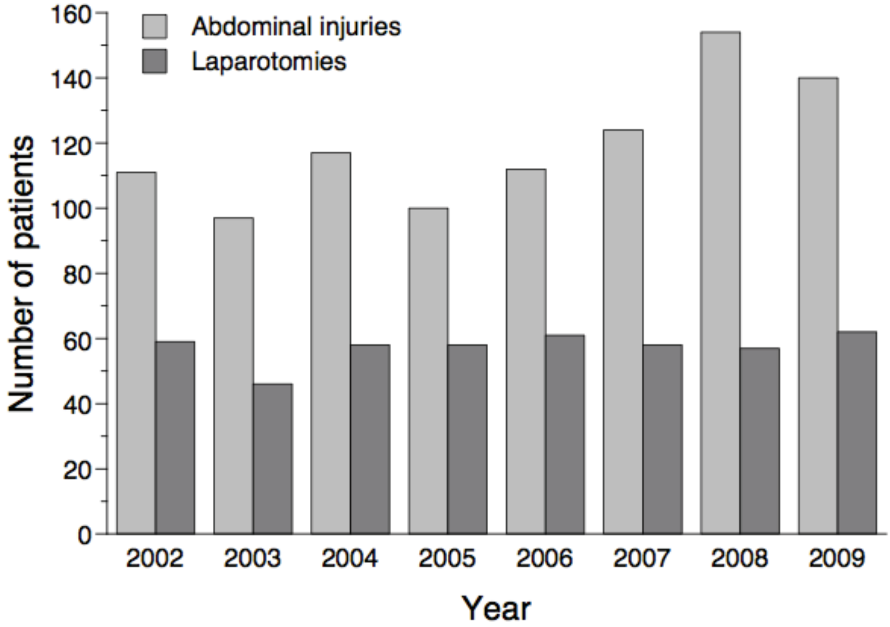

Figure 1 Year by year numbers of patients with abdominal injury and patients undergoing laparotomy

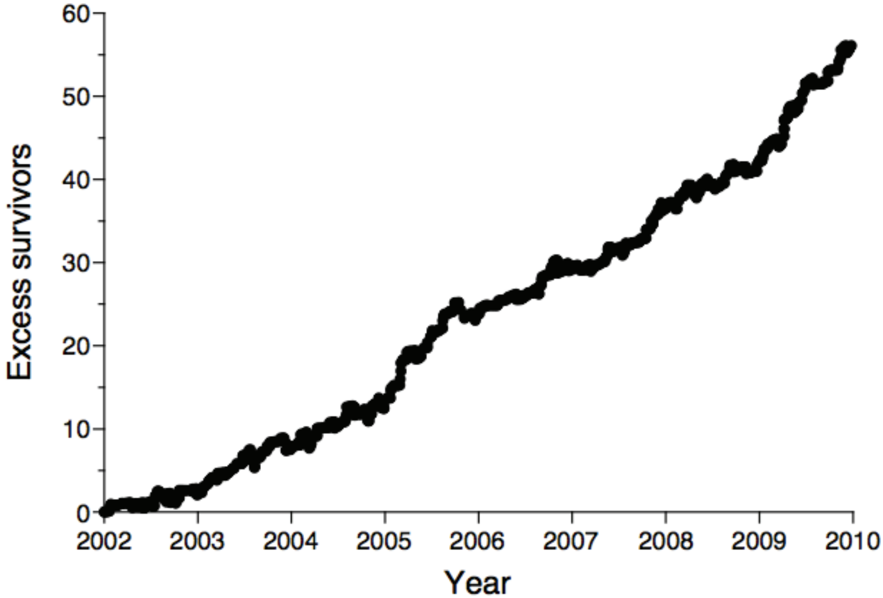

Figure 2 Cumulative excess survival for patients with abdominal injury

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Effects of moving emergency trauma laparotomies from the ED to a dedicated OR

Sigrid Groven[1,2,4*], Paal Aksel Naess[1], Nils Oddvar Skaga[3] and Christine Gaarder[1]

Abstract

Introduction: The trauma room at Oslo University Hospital- Ulleval is fully equipped for major damage control procedures, in order to minimize delay to surgery. Since 2006, patients in need of immediate laparotomy have increasingly been transferred to a dedicated trauma operating room (OR). We wanted to determine the decrease in number of procedures performed in the emergency department (ED), the effect on time from admission to laparotomy, the effect on non-therapeutic laparotomies, and finally to determine whether such a change could be undertaken without an increase in mortality.

Methods: Retrospective evaluation of haemodynamically unstable trauma patients undergoing laparotomy during the period 2002–2009. Based on time for protocol change Period 1 was defined as 2002–2006 and Period 2 as 2007–2009. Significance was set at $p < 0.05$.

Results: A total of 167 consecutive patients were included; 103 patients from Period 1 and 64 from Period 2. We found a 42% decrease in ED laparotomies ($p < 0.001$). Median time to laparotomy increased from 24.0 to 34.0 minutes from Period 1 to Period 2 ($p = 0.029$). Crude mortality fell from 57% to 39%. The proportion of non-therapeutic laparotomies in the OR tended to be lower over the whole study period.

Conclusion: Moving this cohort of haemodynamically compromised trauma patients in need of emergency laparotomy out of the ED to a dedicated OR resulted in longer median time to laparotomy, but did not increase mortality.

Keywords: Trauma, Abdominal injury, Laparotomy, Emergency department, Survival

Introduction

Haemodynamically compromised trauma patients with suspected abdominal bleeding need immediate attention from a multidisciplinary team, and the primary aim should be to control haemorrhage. Any delay before surgery may adversely affect outcome [1,2].

Time from emergency department (ED) arrival to laparotomy has been used extensively as an audit filter in performance improvement processes [3-5]. Clarke et al. demonstrated that time to laparotomy for intra-abdominal bleeding does affect survival, increasing the risk of death by 1% for every 3 minutes delay [6].

In order to minimize delay to surgery, the treatment protocol at Oslo University Hospital-Ulleval (OUH-U) until 2006 encouraged major damage control procedures including laparotomies to be performed in a 3-bed trauma room in the ED. However, although fully equipped for major surgical procedures, conditions for operating in the ED setting are suboptimal, since the room does not meet the requirements of a formal operating room. Moreover, blocking the trauma room affects preparedness in an increasingly busy trauma center environment.

In spite of the risk of increasing time to surgery, a change in protocol was made in 2006, mandating patients in need of trauma laparotomy to be transferred to the dedicated trauma operating room (OR) one floor above the ED, when deemed possible.

The aim of this study was to detect the effect of moving emergency trauma laparotomies in patients with cardiac activity on presentation, from the trauma room in the ED to the dedicated OR. We wanted to determine

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the decrease in the number of laparotomies performed in the ED, the effect on time from admission to laparotomy, as well as on the non-therapeutic laparotomy rate. Finally, we wanted to determine whether this change – potentially challenging time as an accepted performance indicator – could be undertaken without an increase in mortality.

Patients and methods

OUH-U is a major Scandinavian trauma center currently admitting approximately 1,600 trauma patients per year. Blunt trauma is the mechanism of injury in 90% of the patients. Consistently, approximately 40% are severely injured with an injury severity score (ISS) >15 [7].

The current study is a retrospective analysis of all haemodynamically unstable trauma patients undergoing laparotomy and entered into the institutional trauma registry during the period January 1, 2002 to December 31, 2009. Patients were excluded if they had undergone laparotomy at the local hospital before transfer to OUH-U. During the same period, no patient could be identified to have died of intraabdominal haemorrhage without having undergone laparotomy.

The treatment protocol throughout the study period was focused on physiology, and with intra-abdominal haemorrhage identified with DPL or FAST in haemodynamically unstable patients. Emergency room thoracotomy (ERT), with cross-clamping of the aorta followed by laparotomy when indicated is performed in the unresponsive exsanguinated patient who has shown signs of life within the last 15 minutes, and obviously severe abdominal bleeding with a systolic blood pressure (sBP) < 60 mmHg with no response to fluid resuscitation. Other patients with a transient response with suspected intra-abdominal bleeding would undergo emergency laparotomy. The patients who are haemodynamically normalizing upon initial resuscitation and with suspected abdominal injury would routinely undergo CT scan before further procedures.

The change in 2006 consisted in rapid decision-making and transfer to a dedicated OR one floor above the ED when physiology allowed. Indications for ERT remained unchanged throughout the study period [8], whereas in Period 2 further operative procedures such as laparotomy required confirmed cardiac activity, since systematic trauma auditing had revealed that some laparotomies had been performed in patients where emergency room thoracotomy with cross-clamping of the aorta had not been successful in reestablishing cardiac activity. The institutional massive transfusion protocol was updated to a balanced use of red cells, plasma, and platelets in 2007.

The patient was defined as unstable by the trauma team leader when sBP on admission was <90 mmHg and the patient was not responding adequately to initial resuscitation.

The protocol change required a change in attitude in the trauma teams and thus the change happened gradually in 2006. We therefore chose to use January 2007 as the cut-off point in time for the current study. Period 1 was thus defined as January 1, 2002 to December 31, 2006 and Period 2 as January 1, 2007 to December 31, 2009.

Data extracted from the OUH Trauma Registry included age, gender, mechanism of injury, ISS, Glasgow coma scale (GCS) score, surgical procedure codes, 30-day survival, and main cause of death based on patient charts and autopsy reports when available. Multiple organ failure (MOF) was defined as failure of two or more organ systems according to accepted definitions. The trauma registry includes all trauma patients admitted through trauma team activation (irrespective of ISS), or with penetrating injuries proximal to elbow or knee, or with ISS ≥ 9 admitted to OUH-U directly or via a local hospital within 24 hours after injury. Transfers more than 24 hours after injury are included only if the trauma team is activated. Anatomic injury was classified according to the Abbreviated Injury Scale 1998 (AIS-98) [9]. Data on surgical procedures were used to identify patients who had undergone laparotomy. Details about the surgical procedures were then extracted from the patient charts.

Laparotomies were deemed futile and were excluded if performed after emergency thoracotomy in the ED in a patient with cardiac arrest or pulseless electrical activity (PEA), and who was declared dead without having regained adequate cardiac function. Non-therapeutic laparotomy was defined as absence of intra-abdominal injury or injury not requiring intervention.

In order to assess whether the patients surviving ED laparotomy could have been transferred to the OR and whether the patients dying in the OR could have been saved with an ED laparotomy, an audit process was performed where all patient charts were reviewed by three of the authors (SG, PAN, CG). In case of different conclusions, consensus was reached by discussion.

Statistical methods

Chi square and Fisher's exact tests were used for analyses of categorical data, and Student's t test and Mann–Whitney U test were used for normally (presented as mean (SD)) and non-normally (presented as median (interquartile range)) distributed continuous data, respectively. Statistical analyses were performed using PASW Statistics 18 statistical software (SPSS Inc., Chicago, USA). A p value of < 0.05 was considered to indicate significance.

Risk adjustment in this study was based on TRISS-methodology [10]. We employed TRISS regression coefficients published by the US National Trauma Data Bank in 2005. W-statistics, expressing excess survivors per 100 patients treated at OUH-U compared to TRISS model predictions [11] was calculated according to convention and used to compare outcomes for the two periods. Non-overlapping 95% confidence intervals were deemed as significant differences between groups.

The study was approved by the Data Protection Officer, and the Regional Committee for Medical Research Ethics had no objections.

Results

Period 1 vs. period 2

A total of 192 unstable patients underwent laparotomy during the whole study period. Of these, 25 laparotomies were futile and the patients were thus excluded. The remaining 167 patients constitute our study population, with 103 included in Period 1 and 64 in Period 2. Patient data for the two periods were compared for demographics and outcome (Table 1). Figure 1 shows year by year numbers of unstable patients undergoing laparotomy and unstable patients undergoing ED laparotomy. Emergency room thoracotomy (ERT) was performed in 40 of the patients during Period 1 and 9 patients in Period 2.

There was a significant decrease in ED laparotomies from 64% in period 1 to 22% in period 2 (Table 1) ($p < 0.001$). We found a decrease in crude mortality from 57% in Period 1 to 39% in Period 2 ($p = 0.026$). However, when adjusting the numbers for case mix according to TRISS (W-statistics), this apparent reduction did not reach significance, as demonstrated by overlapping 95% confidence intervals (Table 1). Median time to laparotomy was 24.0 minutes in Period 1 and 34.0 minutes in Period 2 ($p = 0.029$) (Table 1). The appearant difference in non-therapeutic laparotomy rate between ED and OR seems to have disappeared in Period 2 (Table 1).

The rate and distribution of main causes of death remained unchanged (Table 2).

ED laparotomy vs. OR laparotomy

A total of 80 patients underwent laparotomy in the ED during the study period, while 87 underwent laparotomy in the OR. Demographics are listed in Table 3. Not surprisingly, the patients undergoing laparotomy in the ED were more physiologically compromised and more severely injured. The crude mortality rate for ED laparotomy was 68% compared to 34% for patients undergoing laparotomy in the OR ($p < 0.001$). However, when adjusting the numbers for case mix according to TRISS

Table 1 Demographics and outcome for unstable patients undergoing laparotomy in period 1 and 2

	Period 1 n = 103	Period 2 n = 64	*p*
Age			
mean (SD)	39.4 (20.0)	37.9 (16.7)	0.612
Male (%)	74 (72)	48 (75)	0.722
Blunt (%)	88 (85)	52 (81)	0.520
GCS score			
median (interquartile range)	6.0 (10.0)	12.0 (8.0)	0.003
Admission BP			
mean (SD)	80 (34)	76 (31)	0.473
Admission BE			
mean (SD)	−11 (7)	−11 (7)	0.609
ISS			
mean (SD)	43 (16)	36 (17)	0.011
Deaths (%)	59 (57)	25 (39)	0.026
W NTDB 05 (95% CI)	1.97 (−4.37 to 8.30)	0.22 (−8.42 to 8.86)	
Laparotomy in ED (%)	66 (64)	14 (22)	<0.001
Non-therapeutic laparotomies overall (%)	28 (27)	13 (20)	0.359
In ED (%)	19 (18)	6 (9)	0.124
In OR (%)	9 (9)	7 (11)	0.788
Time to emergency laparotomy (minutes)			
median (interquartile range)	24.0 (32.0)	34.0 (27.8)	0.029

GCS: Glascow Coma Scale; BP: systolic blood pressure; BE: base excess; ISS: injury severity score; W NTDB 05: W-statistics with coefficients from National Trauma Data Bank 2005; CI: confidence interval; ED: emergency department; OR: operating room.
Admisson BP is missing for 13 patients in Period 1 and 1 patient in Period 2. Admission BE is missing for 2 patients in Period 1 and 7 patients in Period 2.

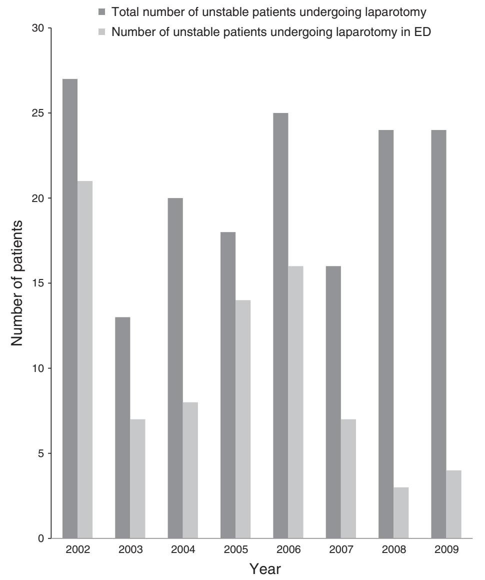

Figure 1 Annual number of haemodynamically unstable trauma patients undergoing laparotomy and subgroup performed in the ED.

(W-statistics), this apparent reduction did not reach significance (Table 3). There was a trend towards more non-therapeutic laparotomies in the ED than when performed in the OR (31% vs 18%, respectively; p = 0.072).

The audit process did not identify any of the 30 patients who died in the OR in whom a laparotomy performed in the ED would have changed outcome. Median time to OR laparotomy was 40.0 minutes. The 26 patients surviving ED laparotomy could have been safely transferred to the OR.

Discussion

A significant decrease in emergency laparotomies performed in the ED was obtained, especially towards the end of the study period. The change could be done without a concomitant increase in mortality, in spite of an increase in median time to laparotomy. It is well known that control of bleeding is important, and therefore time to emergency laparotomy has been used as a quality indicator to assess efficiency and performance of the institution [3,12,13]. However, recent publications fail to find enough evidence to support this and to prove the validity of other commonly used quality indicators in trauma care [14-16]. Recent publications advocate operating capabilities and hybrid solutions closer to the ED due to the time aspect. A formal OR or hybrid suite in or close to the ED was not a realistic option in our institution in 2006, and was no argument against optimizing perioperative conditions when possible by moving the patient to a formal OR.

According to the review process, it is unlikely that a laparotomy performed in the ED would have changed outcome in any of the patients who died in the OR. Similarly, all 26 patients surviving ED laparotomy could have been transferred to the OR without consequences for outcome. However, given that the teams and surgical approach are the same in the ED and the OR, in some patients where ED thoracotomy had been performed, followed by therapeutic laparotomy including extraperitoneal pelvic packing, completing the operative treatment in the ED seemed practical, and justifies maintaining the capability to do so.

The trauma team's primary task is to save lives, while hasty, futile and non-therapeutic procedures should be avoided. The surgical trauma team leader's experience with critically injured patients will influence decision-making and outcome [17-19]. Several authors have addressed the importance of trauma surgical consultant presence in the early phase [19-21]. We have previously described the surgical trauma team leader role in our institution as filled by experienced general surgeons at the end of their surgical subspecialization, but most often with limited trauma experience [22]. The trauma team leaders attend an extensive training program, but typically stay in the role as trauma team leader for only 1.5 years due to the time limits of their training appointment. Our group also published the volume of trauma laparotomies per trauma team leader to be limited to an average of 10 per year [22]. The current findings support the need for a dedicated trauma surgical consultant presence in the early phase of the critically injured patients, as this limited experience undoubtedly also has impact on other aspects of trauma care.

This study has weaknesses in addition to the ones associated with its retrospective nature. The study addresses two consecutive periods, with the possibility of other factors influencing outcome measures as part of the ongoing quality improvement program, such as the implementation of the updated massive transfusion

Table 2 Main causes of death

	Period 1		Period 2		
	N	%	N	%	*p**
Bleeding	40	68	15	60	0,62
Sepsis/MOF	5	8.5	3	12	0,69
Head injury	9	15	4	16	1,00
Other/unknown	5	8.5	3	12	0,69
Total	59	100	25	100	

MOF: multiple organ failure; *Fisher's Exact tests for individual causes against the sum of all other causes.

Table 3 Comparison of patients undergoing OR and ED laparotomies for the whole study period

	Laparotomy in OR n = 87	Laparotomy in ED n = 80	*p*
Age			
mean (SD)	40.0 (18.9)	37.7 (18.6)	0.434
Male (%)	63 (72)	59 (74)	0.863
Blunt (%)	71 (82)	69 (86)	0.529
GCS score			
median (interquartile range)	12.0 (8.0)	3.5 (8.0)	<0.001
Admission BP			
mean (SD)	85 (27)	70 (37)	0.003
Admission BE			
mean (SD)	−9 (5)	−13 (7)	<0.001
ISS			
mean (SD)	38 (17)	42 (16)	0.097
Deaths (%)	30 (35)	54 (68)	<0.001
W NTDB 05 (95% CI)	4.55 (−2.95 to 12.05)	−2.19 (−9.11 to 4.72)	
Non-therapeutic laparotomies, n patients (%)	16 (18)	25 (31)	0.072
Time to emergency laparotomy (minutes)			
median (interquartile range)	40.0 (29.5)	17.0 (15.3)	<0.001

ED: emergency department; OR: operating room.
GCS: Glascow Coma Scale; BP: systolic blood pressure; BE: base excess; ISS: injury severity score; W NTDB 05: W-statistics with coefficients from National Trauma Data Bank 2005; CI: confidence interval.

protocol in 2007. Another example is that on-going efforts to optimize teamwork in the ED might have counteracted the trend towards an increase in time to laparotomy from Period 1 to Period 2, as well as the decrease in laparotomies following ERT. Given that the indications for ERT remained unchanged during the study period [8], the reduction in the number of ERTs preceding laparotomy from Period 1 to Period 2 likely reflects the fact that laparotomy was no longer performed unless cardiac activity had been regained. The fact that the difference in non-therapeutic laparotomies between ED and OR seemed to have disappeared in Period 2 might have been due to better decision-making with improved educational programs. However, the numbers are too small for any firm conclusions.

Our group has recently shown that the beginning of long-lasting improvement in performance with increased survival in our total trauma population coincided with the formalization of a Trauma Service in 2005 [23]. A range of changes were made over the study period, both before and after 2005, influencing patient outcomes in general. Although not being able to adjust for all confounders, the value of critical evaluation of implemented changes should not be underestimated.

Comparison of crude mortality rates without adjusting for the risk profile of the patients is of limited value. The intention with risk adjustment is to remove sources of variation that are institution independent. Anatomic injury, physiological derangement, age, and injury mechanism are well-founded predictors of trauma outcome, all implemented in the TRISS-methodology. Thus, differences in case mix in our study are adjusted for in the survival prediction models, showing no significant difference in mortality rates. One could speculate that this difference in case-mix would explain the difference in ED laparotomy rate. However, given the comparable haemodynamics (sBP, BE), it is unlikely that the difference in GCS and ISS would account for the higher ED laparotomy rate in Period 1.

The categorization of the patients as unstable and the laparotomies as non-therapeutic was based on subjective evaluation of patient charts, but strengthened by creating consensus between three of the authors. The same applies for the evaluation of OR deaths and ED survivors. The influence of this subjectivity would likely affect both periods similarly.

Conclusion

Moving this cohort of haemodynamically compromised trauma patients in need of emergency laparotomy out of the ED to a dedicated OR resulted in longer median time to laparotomy, but did not increase mortality.

Competing interests
None of the authors had any conflict of interest and there were no sources of funding.

Authors' contributions
SG, PAN, NOS and CG designed the study. SG and NOS performed the data collection. The statistical analysis of the data was performed by SG. SG drafted the manuscript assisted by PAN, NOS and CG. All authors contributed to the interpretation of the data and writing of the manuscript. All authors revised the manuscript and approved it in the final form.

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IV

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ORIGINAL RESEARCH **Open Access**

A national survey on temporary and delayed abdominal closure in Norwegian hospitals

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Abstract

Introduction: Temporary abdominal closure (TAC) is included in most published damage control (DC) and abdominal compartment (ACS) protocols. TAC is associated with a range of complications and the optimal method remains to be defined. The aim of the present study was to describe the experience regarding TAC after trauma and ACS in all acute care hospitals in a sparsely populated country with long transportation distances.

Material and methods: A questionnaire was sent to all 50 Norwegian hospitals with acute care general surgical services.

Results: The response rate was 88%. A very limited number of hospitals had treated more than one trauma patient with TAC (5%) or one patient with ACS (14%) on average per year. Most hospitals preferred vacuum assisted techniques, but few reported having formal protocols for TAC or ACS. Although most hospitals would refer patients with TAC to a trauma centre, more than 50% reported that they would perform a secondary reconstruction procedure themselves.

Conclusion: This study shows that most Norwegian hospitals have limited experience with TAC and ACS. However, the long distances between hospitals mandate all acute care hospitals to implement formal treatment protocols including monitoring of IAP, diagnosing and decompression of ACS, and the use of TAC. Assuming experience leads to better care, the subsequent treatment of these patients might benefit from centralization to one or a few regional centers.

Keywords: temporary abdominal closure, damage control surgery, abdominal compartment syndrome, survey

Introduction

Damage control techniques as well as prevention and treatment of abdominal compartment syndrome (ACS) includes the use of temporary abdominal closure (TAC), resulting in the clinical challenges of open abdomen-related morbidity. A wide variety of TAC techniques exists, including commercial or improvised vacuum-assisted closure, permanent or absorbable prosthetic mesh insertion, Bogota bag, or strategies using native tissue only, leaving the optimal TAC yet to be defined. There is no standardization of terminology or accepted guidelines for when to leave the abdomen open, and controversy exists among surgeons as to which of the different options for TAC to select [1].

All TAC techniques are associated with a range of complications, as surgical site infections, sepsis, prolonged stay in the intensive care unit (ICU), enteroatmospheric fistulas and large hernias [2-9]. Follow-up of patients with an open abdomen demands multidisciplinary teamwork. The optimal management of the open abdomen remains one of our major surgical challenges [1,10].

Only few published surveys address this complex patient group, showing absence of standardized approach, and a wide variation in clinical management [1,11].

Through a national survey, the aim of the present study was to describe the experience regarding TAC in the trauma context and in patients with ACS regardless of etiology in all acute care hospitals in a sparsely populated country with long transportation distances.

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Materials and methods

Norway is a sparsely populated country, covering 323.000 square kilometers with a population of 4.7 million people. There is a total of 50 hospitals with acute care surgical facilities, resulting in low patient volumes and long transportation distances for many of the hospitals.

A questionnaire (Figure 1) was in March 2009 sent to one attending surgeon in every general/gastrointestinal (GI) surgical department in all hospitals with acute care surgical facilities in order to assess the experience with TAC in the trauma context and in patients with ACS regardless of etiology over the last five years. Questionnaires were coded to maintain confidentiality and to track hospitals having responded for the purpose of avoiding unnecessary renotification. To increase the response rate a renotification was sent after two months. A follow-up internet-based questionnaire (Figure 2) to assess protocols and routines in this field was sent to the same departments one year after the initial survey.

1 **ACS during the last 5 years in your hospital?**
Yes
No
If yes, number of patients?
2 **TAC after trauma during the last 5 years?**
Yes
No
If yes, number of patients?
3 **Indications for TAC in your hospital?**
DCS
ACS
Other indications
4 **Preferred method for TAC?**
Bogota bag
Vac pack
KCI V.A.C.®
Wittman patch
Other procedures
5 **Definitive surgery after DCS**
Is performed in my hospital
The patient is referred to a trauma center
6 **Secondary reconstruction after TAC**
Is performed in my hospital
The patient is referred to a trauma center

ACS, abdominal compartment syndrome; TAC, temporary abdominal closure; DCS, damage control surgery; V.A.C.®, vacuum-assisted closure.

Figure 1 Initial questionnaire.

1 **Treatment protocol for ACS in your hospital?**
Yes
No
2 **Routines for measuring IAP in your hospital?**
Yes
No
3 **Procedure for measuring IAP?**
Bladder pressure
Gastric pressure
Other methods
4 **Written procedure for TAC in your hospital?**
Yes
No

ACS, abdominal compartment syndrome; IAP intraabdominal pressure; TAC, temporary abdominal closure.

Figure 2 Follow-up internet-based questionnaire.

Results

Completed questionnaires were received from 44 of the 50 hospitals including 4 out of 5 regional trauma centres, yielding a response rate of 88%. Twelve of the hospitals (27%) had treated trauma patients with TAC during the last five years, and only 2 of these hospitals had treated more than one patient on average per year.

Most hospitals reported that they would use well established techniques for TAC, with 25 hospitals preferring a modified Opsite® sandwich technique (vacuum pack) [12] and 12 hospitals reporting that they would use the KCI V.A.C.® (Kinetic Concepts Inc. International, San Antonio, TX, USA). Only 3 hospitals would use the Bogota bag, while 9 hospitals chose another, unspecified method. Several hospitals reported more than one type of procedure.

A total of 27 hospitals (61%) reported that they would refer patients with TAC after damage control surgery (DCS) to a trauma centre, while the rest would perform the definitive surgical treatment of the injury and closure of the abdomen themselves. If secondary reconstruction after TAC was indicated, only 21 of the 44 hospitals (48%) would have transferred the patient to a regional centre.

In addition to DCS, 23 of the hospitals (52%) reported ACS regardless of etiology as an indication for TAC. A total of 22 hospitals (50%) reported having treated patients with ACS, but only 6 hospitals had treated more than one patient on average per year.

The follow-up survey was conducted to describe existing protocols and routines for TAC, ACS and monitoring of intraabdominal pressure (IAP). Completed questionnaires were recieved from 31 of the 50 hospitals, yielding a response rate of 62%. Of these 31 hospitals, 24 (77%) reported having routines for measuring IAP in risk patients. Bladder pressure measurement was the only reported method. Formal protocols for treating

ACS existed in only 10 hospitals, while 11 hospitals reported having formal protocols for TAC.

Discussion

This national survey indicates that most surgical departments have limited experience with this complex patient group, with only 2 hospitals reporting having treated more than one trauma patient with TAC on average per year over the study period. Accordingly, only 6 hospitals reported having treated more than one patient with ACS on average per year, regardless of etiology. Our findings seem to be in agreement with Kirkpatrick et al. [1], showing no consensus nor standard methods for closure of the open abdomen among the members of Trauma Association of Canada. Karmali et al. [11] assessed the opinion of the same group of Canadian trauma surgeons while Mayberry et al. [13] assessed the opinion of members of the American Association for the Surgery of Trauma. Through description of physicians' response to various clinical scenarios, they revealed a widespread knowledge on ACS [13], while no particular procedure for TAC seemed to have gained general acceptance [11].

Addressing members of professional societies carries the inherent risk of getting several answers from some hospitals and none from others. In contrast to the above mentioned surveys, our study is the first to address all general surgical departments in a country regarding their experience with TAC and ACS, and achieving a high response rate.

An ideal TAC should cover and protect abdominal contents, manage excessive fluid, avoid damaging the fascia, minimize loss of domain, limit risk for complications and facilitate reoperation and closure [14]. The negative pressure techniques report low incidence of complications and high closure rates [3,4,7,14-16], and are recommended- at least in the initial phase- by the Open Abdomen Advisory Panel in 2009 [14]. Although only about one third of the hospitals in Norway state having standardized protocols for TAC, the current practice seems to be according to these recommendations.

Primary ACS in centres with appropriate level of awareness should now be extremely rare [10]. However, Kimball et al. [17] revealed that among members of the Society of Critical Care Medicine, 82,8% of the respondents had treated one or more patients during the last year. Tiwari et al. [18] did a survey of ICUs in the United Kingdom revealing that 96,9% of the teaching hospitals and 72,6% of the district general hospitals had seen ACS. In our study 50% of the hospitals reported having treated patients with ACS during the last five years, but only 13% had treated more than one patient per year on average. Ravishankar et al. [19] showed that many intensive care units in the United Kingdom never measure IAP. In our follow-up survey, 77% of the hospitals reported having routines for measuring IAP. However, our study does not assess whether the correct risk patients are identified, with the potential of giving us an underestimate of the actual incidence.

The follow up of patients with TAC is complex and requires extensive multidisplinary teamwork and experience [1,11,14]. After damage control resuscitation and application of TAC, the patient proceeds through phases with different management goals. The optimal final aim is to achieve definitive abdominal closure within the initial hospitalization, and with as few complications as possible. Norway is a sparsely populated country with long transportation distances much like other rural areas worldwide, mandating hospitals providing acute care and initial trauma care to have procedures for damage control and TAC. Given the low patient volume and limited experience revealed in the present survey these patients might benefit from referral to a centre with surgical experience and necessary critical care resources, to optimize further treatment.

A proportion of the patients will have fascial defects that cannot be closed during the initial hospitalization. When secondary reconstruction is indicated, more than half of the respondents in our study would have performed the surgery locally- even though their experience is limited. For some of the hospitals it remains a hypothetical problem, since more than 70% reported not having treated a trauma patient with TAC during the last five years.

The study has several additional limitations. It is retrospective and subject to recall bias due to the lack of trauma and critical care registries in most hospitals. ICUs in Norway are run by anaesthesiology trained intensivists. However, surgeons are involved in the care of their patients in ICU and should be aware of patients at risk of IAH and ACS. The questionnaires did not explore the use of TAC as part of the strategy to avoid ACS in other patient categories than trauma, hence the number of patients treated with TAC in each hospital might be underestimated. Finally, the surgeons' subjective response might not correspond to the hospitals' current clinical practice.

Conclusion

This study shows that most Norwegian hospitals have limited experience with TAC and ACS. However, the long distances between hospitals mandate all acute care hospitals to implement formal treatment protocols including monitoring of IAP, diagnosing and decompression of ACS, and the use of TAC. Assuming experience leads to better care, the subsequent treatment of these patients might benefit from centralization to one or a few regional centers.

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Authors' contributions
SG, PAN and CG had the original idea for the study and developed the questionnaires. SG developed the database. Data were analyzed by all authors. All authors contributed in the preparation of the manuscript.

Competing interests
The authors declare that they have no competing interests.

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