Occasional Reviews

Anaesthetic management of acute blunt thoracic trauma

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Sunnybrook Health Science Centre is an adult regional trauma unit serving metropolitan Toronto and environs. We undertook a two-year retrospective review of patients admitted to our institution with blunt thoracic trauma. Three hundred and thirty-three patients with blunt trauma and an injury severity score (ISS) greater than 17 required emergency surgery. Of these, 208 had blunt thoracic injuries while 125 did not have chest injuries. Both groups were similar with respect to age but patients with thoracic trauma had a greater ISS. ($P < 0.05$) and greater intraoperative mortality ($P < 0.01$). The aetiology of the intraoperative deaths with one exception was exsanguination. Emergency thoracotomy or sternotomy indicated a poor prognosis with a mortality rate of 80%. The most common intraoperative problem was an elevated airway pressure. Awake intubation was undertaken in 77.5% of patients requiring anaesthesia and surgery because of the potentially compromised airways and difficult intubations due to the nature of the associated injuries. Finally, 74% of patients undergoing urgent surgery required mechanical postoperative ventilation. The presence of blunt chest trauma should be considered a marker of the severity of injury sustained by the patient.

Le Sunnybrook Health Science Centre est le centre de traumatologie adulte desservant le Toronto métropolitain. Nous avons revu les cas de traumatismes fermés du thorax qui y furent admis depuis deux ans. Nous avons recensé 333 cas de traumatisme fermé important chez qui une intervention chirurgicale urgente s'avéra nécessaire. On a dénombré parmi eux 208 traumatismes du thorax. L'âge moyen était le même qu'il y ait ou non

implication thoracique toutefois, cette dernière entraînait un score de gravité moins réjouissant ($P < 0.05$) et une mortalité per-opératoire plus grande ($P < 0.01$). Sauf exception, les décès per-opératoire survenaient par exsanguination. Les thoracotomies et sternotomies d'urgence étaient de mauvais augure avec une mortalité de 80%. En per-opératoire, les pressions des voies respiratoires étaient souvent très élevées. Des voies respiratoires supérieures déformées et d'autres blessures laissant anticiper des difficultés lors de l'intubation, nous ont fait opter pour une intubation éveillée dans 77,5% des cas nécessitant une anesthésie. Enfin, après l'intervention chirurgicale nous avons dû ventiler mécaniquement 74% des patients. La présence d'un traumatisme fermé du thorax assombrit le pronostic des victimes d'accident.

Key words

ANAESTHESIA: emergency;

COMPLICATIONS: mortality, trauma, chest.

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There is a lack of information in the anaesthetic literature regarding the intraoperative management of blunt thoracic trauma. Most reports have originated in the United States of America where blunt and penetrating injuries are frequently combined and described together.^{1,2} The estimated proportion of penetrating injuries is greater in the United States than in Canada.³ As a result, the American experiences may not necessarily be extrapolated to Canada. Sunnybrook Health Science Centre is a level I adult regional trauma unit in southern Ontario which serves northern metropolitan Toronto and surrounding districts. We receive about 500 trauma victims annually, which accounts for approximately 57% of all trauma admissions in the region of metropolitan Toronto and environs. Ninety-six percent of admissions are due to blunt injuries. We have undertaken a two-year review of our experience in the perioperative management of patients with acute blunt thoracic trauma.

Methods

The charts of all patients admitted to our institution between July 1, 1985 and June 30, 1987, with injuries induced by blunt trauma were reviewed retrospectively. All injuries were catalogued and assigned according to the Abbreviated Injury Scale (AIS). This scoring system is a

comprehensive catalogue that classifies all injuries by type, anatomical location and severity.⁴ An injury severity score (ISS) is obtained by taking the three most severely injured body regions and summing the squares of the AIS scores.⁵

The criteria for inclusion in the review were an ISS greater than 17 and performance of urgent or emergency surgery within 24 hr of admission. To achieve an ISS of 17 or greater a patient must have severe injuries in two or more body regions as defined by the American Medical Association's Committee on the Medical Aspects of Automobile Safety.⁴ Patients were divided into two groups based on the presence or absence of blunt thoracic injuries as defined by an AIS of two or greater in the thoracic region including single rib fractures. Examples of such AIS scores include: flail chest which scores (4), pulmonary contusion (3) and simple pneumothorax (3). Patients requiring an emergency operative procedure and having extensive thoracic trauma were designated Group 1. Those without chest trauma requiring urgent surgery were designated Group 2. Patients were reviewed and compared with respect to the following: severity of injury (ISS), age and intraoperative mortality. The AIS and ISS were calculated prospectively by a blinded individual.

Patients with thoracic trauma were further evaluated according to the nature of the thoracic injuries, associated injuries in other body regions requiring surgery, intraoperative respiratory complications, intraoperative monitoring, anaesthetic technique, method of tracheal intubation and requirement for mechanical postoperative ventilation. The technique and method of tracheal intubation was studied in the second year of the review only.

Groups 1 (thoracic trauma) and 2 (no thoracic trauma) were compared with respect to age and ISS utilizing unpaired *t* tests for large samples with a Bonferroni correction for multiple testing. Intraoperative mortality was compared using Chi-square analysis. In all instances $P < 0.05$ was considered significant.

Results

Seven hundred and eighty patients were admitted to our institution after sustaining blunt trauma during the study period. Three charts could not be retrieved. Five hundred and one had an ISS > 17 and of these 333 required urgent surgery within the first 24 hr of admission. Two hundred and eight patients required an emergency operative procedure and had thoracic trauma (Group 1). There were 125 patients without chest trauma requiring urgent surgery (Group 2).

Mortality

There was a total of 102 deaths in the 780 trauma admissions, including those dead on arrival in the

TABLE 1 Mean ($\pm$ SD) age and ISS of 333 patients with and without thoracic injuries

	<i>n</i>	Age	ISS
Group 1	208	36.7 (19.2)	35.7 (10.5)
Group 2	125	32.3 (16.3)	29.9 (9.5)
		NS	$P < 0.05$

emergency room, resulting in an overall crude mortality rate of 13.1%. Of the 333 patients who had an ISS > 17 requiring urgent surgery within 24 hr of admission, there were 17 intraoperative deaths. Sixteen deaths occurred intraoperatively in Group 1 resulting in an intraoperative mortality rate of 7.7% while only one patient in Group 2 died intraoperatively, a mortality rate of 0.8% ($P < 0.01$). All of the intraoperative deaths with one exception in Group 1 were the result of exsanguination. The remaining patient died from asphyxia due to haemorrhage into the tracheobronchial tree. Only four of the 20 patients undergoing urgent thoracotomy or sternotomy within the first 24 hr of admission survived. Fourteen patients died in the operating room while two died in the intensive care unit.

Haemorrhage

The source of haemorrhage in the Group 1 patients dying in the operating room included abdominal cavity (4), intrathoracic inferior vena cava (4), pelvis (2), thoracic aortic rupture (2), pulmonary artery rupture (1), chest wall (1) and head (1). Both patients dying with thoracic aortic disruption arrived at our institution after aortic rupture. The source of haemorrhage of the single Group 2 patient was the pelvis.

Injuries

Group 1 patients were more extensively injured than those in Group 2 (Table 1) yet their ages were similar. Most patients in Group 1 had more than one thoracic injury (Table II). Table III catalogues the associated injuries of patients with blunt thoracic trauma by anatomical region. Emergency surgical procedures carried out on patients with blunt thoracic trauma within the first hours of admission are presented in Table IV.

Respiratory problems

An elevated peak airway pressure, defined as an airway pressure ≥ 35 cm water, was present in 82 patients. The cause of the raised airway pressure was attributed to haemorrhage into the tracheobronchial tree (13 patients), pulmonary oedema (9), intraoperative pneumothorax (2), lobar collapse (1), and aspiration (1). The aetiology of elevated peak airway pressure in the remaining 56 patients

TABLE II Thoracic injuries in 208 patients with blunt chest trauma

Associated injury	n	% with blunt chest trauma
Fractured rib(s)	140	67.3
Pulmonary contusion(s)	135	64.9
Pneumothorax	63	30.3
Haemothorax	54	26.0
Flail chest	48	23.1
Myocardial contusion	27	13.0
Diaphragmatic rupture	19	9.1
Thoracic aortic injury	10	4.8
Pulmonary laceration	6	2.9
Inferior vena cava tears	4	1.9
Haemopericardium	3	1.4
Fractured sternum	2	1.0
Myocardial rupture	1	0.5
Torn pulmonary artery	1	0.5
Dislocated arytenoid	1	0.5
Torn internal mammary artery	1	0.5

TABLE III Associated injuries, by regions, in 208 patients with blunt thoracic trauma

Associated injuries	n	% with blunt chest trauma
Head injury	102	49.0
Cervical spine	25	12.0
Face (all injuries)	62	29.8
Face (maxillary or mandibular fractures)	38	18.3
Abdomen and pelvic contents	102	49.0
Extremities including bony pelvis	151	72.6
Surface or integument	24	11.5

was not determined. The management of tracheobronchial haemorrhage included suctioning of the endotracheal tube in nine patients and fiberoptic bronchoscopy with aspiration of tracheal secretions and blood in another four patients. Of the patients requiring bronchoscopy one needed placement of a double lumen endobronchial tube and one underwent insertion of a bronchial blocker to isolate bleeding and ensure adequate ventilation and oxygenation. Both patients requiring lung isolation procedures survived the operating room. One patient who did not receive a lung isolation procedure died from asphyxiation due to an airway haemorrhage.

In 23 (11%) instances the lungs were ventilated with a free-standing volume ventilator intraoperatively as the anaesthetist felt that the anaesthesia ventilator with a partial rebreathing circuit was inadequate. Where a volume ventilator was chosen the alveolar-arterial partial pressure gradient for oxygen (A-a-DO₂) and airway pressure tended to be higher (Table V).

In the second year of the review, there were 111

TABLE IV Emergency surgical procedures

Procedure	n	% blunt trauma
Craniotomy	20	9.6
Insertion intra-cranial pressure monitor	56	26.9
Thoracotomy and/or sternotomy	20	9.6
Laparotomy	101	48.6
Orthopaedic procedures	86	41.3

TABLE V Intraoperative ventilation variables

	A-aDO ₂ *	PaW†
Volume ventilator	389	44
Anaesthetic ventilator and partial rebreathing circuit	186	28.6

**P* < 0.001.

†*P* < 0.005.

patients with blunt thoracic trauma requiring emergency surgery. Of these, the tracheas of 25 were intubated with the aid of general anaesthesia and/or muscle relaxants, while in 85 intubation was performed awake with topical anaesthesia. One patient had his airway secured by tracheostomy under local anaesthesia.

Postoperative mechanical ventilation was required in 142 of the 191 (74%) patients with blunt thoracic trauma who survived the operation. The mean duration of ventilation was 7.2 days ($\pm$ 8.1).

Anaesthetic technique

All 208 patients with blunt thoracic trauma presenting to the operating room on an urgent basis had basic anaesthetic monitors such as an ECG, sphygmomanometer, pulse oximeter, capnography, and temperature probe applied. In addition, 193 patients received an arterial catheter, 24 a central venous pressure (CVP) catheter, 15 intra-cranial pressure (ICP) measuring devices and four had pulmonary artery (PA) catheters.

All patients underwent general tracheal anaesthesia with intermittent positive pressure ventilation. The anaesthetic management is summarized in Table VI.

Discussion

The presence of thoracic injury with blunt trauma is usually indicative of a considerable deceleration impact and appears to increase mortality and perhaps morbidity. The leading cause of death was haemorrhage and exsanguination. The most common intraoperative anaesthetic problem was a raised airway pressure. The leading cause of this was attributed to bleeding into the tracheal bronchial tree and pulmonary oedema. All patients with

TABLE VI Anaesthetic management of 208 patients with blunt chest trauma

Anaesthetic technique	n	% of patients
Relaxant only	13	6.3
Relaxant + IV agents	32	15.4
Relaxant + N ₂ O	1	0.5
Relaxant + vapour	2	1.0
Relaxant + IV agents + N ₂ O	21	10.1
Relaxant + IV agents + vapour	34	16.3
Relaxant + IV agents + N ₂ O + vapour	98	47.1
Charts missing anaesthetic data	7	3.3
Total	208	100

thoracic trauma requiring a surgical procedure had surgery performed with general anaesthesia. While routine monitoring was used in all patients, 93% had an arterial catheter placed to assist in the monitoring and resuscitation of the patient. Other monitors were used less frequently. Tracheal intubation was carried out with topical anaesthesia in the majority of patients but a quarter had induction of anaesthesia with a rapid sequence technique. Postoperative mechanical ventilation was required in 74% of patients presenting to the OR with blunt thoracic trauma.

Blunt thoracic trauma carries a substantial morbidity and mortality.⁶⁻⁸ Our overall mortality is comparable with that reported in other series.^{7,8} Patients with blunt thoracic trauma (Group 1) had a greater ISS, as by definition patients without blunt thoracic trauma (Group 2) had one less body system injured. Yet, the ages of both groups were similar, suggesting similar patient populations. It is not surprising then, that the mortality was higher in the Group 1 than in the Group 2 patients. The two chief causes of intraoperative death with blunt thoracic injuries are respiratory failure and exsanguination. In our series, with one exception, patients died from an inability to control haemorrhage during surgery. The source of haemorrhage was found as frequently in the abdomen and pelvis as in the chest. Thoracotomy or sternotomy as a desperation measure for control of haemorrhage appears to have a dismal prognosis. In our series, thoracotomy to cross-clamp the thoracic aorta had no survivors; all patients died in the operating room.

The most common intraoperative airway problem was an elevation in airway pressure. Bleeding into the airway accounted for the largest proportion of identifiable causes. Haemorrhage into the airway, if severe enough, can result in soiling of the remaining good lung leading to profound hypoxaemia. In two patients, bleeding was severe enough to require isolation of the haemorrhagic lung with a double lumen endobronchial tube in one instance and a bronchial blocker in the other. One other patient may have died because this was not done.

Another cause of increased intraoperative airway pressures is pneumothorax. This occurred in only two patients in our series. The reason for such a low frequency may be that it has been our practice to place prophylactic chest tubes in all patients with fractured ribs undergoing anaesthesia with mechanical ventilation. In the two patients who developed pneumothoraces, this had been omitted. Placement of chest tubes in addition to preventing the development of an intraoperative pneumothorax also allows the anaesthetist to monitor ongoing bleeding from the injured hemithorax. Chest tubes should be of sufficient calibre to permit the adequate drainage of blood (≥ 32 French).

Pulmonary contusion results in intraparenchymal haemorrhage, decreased pulmonary compliance and an increased shunt fraction.^{9,10} This also leads to raised airway pressure and difficulties with ventilation.

The most common intraoperative monitor utilized, in addition to routine anaesthetic monitors, was the arterial catheter (92.8%). We advocate the use of an indwelling arterial catheter in patients with blunt thoracic trauma for ongoing blood pressure measurement, blood gas, haematological and chemistry analysis, and because it frees the anaesthetist's hands for the resuscitation. Other monitors such as CVP catheters (11.5%), ICP monitoring devices (7.2%) and PA catheters (1.9%) were used much less frequently. The ability to gain access to arterial blood is particularly important as the gradient between arterial PCO₂ and end tidal CO₂ may be greater than normal and can vary during the case, depending on the degree of bleeding and the adequacy of blood volume replacement.

A large number (18.3%) of patients with blunt thoracic trauma had potentially abnormal airways due to mandibular or maxillary fractures and 12% had documented cervical spine injuries. Therefore, at least 30% of patients with blunt thoracic trauma had potentially difficult tracheal intubation. Our indications for awake intubation are liberal and include: suspected abnormal airway anatomy, either pre-existing or secondary to trauma, unstable cervical spine but also include the patient in whom the cervical spine cannot be assessed, and shock. It is our impression that the use of muscle relaxants in patients with difficult airways may delay attaining an adequate airway whether by intubation aids or surgical means. To our knowledge, there are no data on the effect of awake versus anaesthetized intubation on neurological outcome in patients with head injuries. However, awake intubation is a safe technique in the presence of cervical spine fracture dislocations.¹¹

Twenty-three patients required mechanical ventilation during surgery with a free-standing volume ventilator as a partial re-breathing anaesthesia circuit could not clear carbon dioxide adequately. The aetiology of this problem

was uncertain but may have been related to increased dead space caused by hypovolaemia, progression of a pulmonary contusion, or production of pulmonary oedema induced by over-aggressive resuscitation. Lungs ventilated with free-standing ventilators had higher airway pressures and A-aDO₂ gradients than those managed with the anaesthesia machine ventilator. The requirement for high levels of positive end expiratory pressure in the face of a large intra-pulmonary shunt, combined with a low pulmonary compliance suggests that intraoperative ventilation cannot be provided adequately using a standard anaesthetic ventilator. The disadvantage of most volume ventilators is the inability to administer anaesthetic vapours, thus the analgesic and anaesthetic requirements of the patient must be met with *iv* agents. Our experience suggests that in patients with airway pressures >50 cm of H₂O and an A-aDO₂ < 400 mmHg, a free-standing mechanical ventilator may be of benefit. Carbon dioxide elimination is a major problem in hypovolaemic patients, utilizing a partial re-breathing circuit. This may be especially important in head injury patients. The requirement for hypocapnia in patients with elevated intracranial pressure might best be achieved with the circle system, including an in-line carbon dioxide absorber, rather than a partial re-breathing system. This would allow lower fresh gas flows than those required with a partial re-breathing circuit and would hence reduce peak and mean airway pressures.

Anaesthetic care of these patients often continues into the intensive care unit. A large proportion of patients with blunt thoracic trauma required postoperative ventilatory support. The most common indications for postoperative ventilation appeared to be the severity of head and/or thoracic injuries, as the requirement and the duration of mechanical ventilation appeared to correlate directly with the A-aDO₂ and inversely with the Glasgow coma score.

All patients received general anaesthesia with intermittent positive pressure ventilation. All combinations of general anaesthetic techniques were used. Nitrous oxide was not used in a large proportion of patients (38.9%). The reasons for this included: the concern about using nitrous oxide in the presence of closed air-containing spaces in the central nervous system or the thorax, the necessity of delivering high oxygen concentrations to achieve adequate oxygenation, and the possibility that nitrous oxide may increase pulmonary vascular resistance in patients with pulmonary and myocardial contusions who have elevated pulmonary vascular resistance and right-sided myocardial dysfunction.^{12,13}

In summary, the presence of blunt thoracic trauma in poly-traumatized patients suggests a more severe mechanism of injury, a higher ISS and leads to a greater perioperative mortality. The cause of death in the opera-

ting room is either exsanguination or, less commonly, respiratory failure. As a result, perioperative anaesthetic management should focus on the prevention and management of these two problems. If these are anticipated and dealt with properly, the frequency of intraoperative complications should be reduced.

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