Original Article

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Surgery Section

Outcome Following Chest Tube Removal with Respect to Phase of Respiration in Chest Trauma Patients: A Randomised Controlled Trial

RITESH KUMAR[1], SANDEEP CHAUHAN[2], MAHAVIR SINGH[3], MOHAMMED FAIZ[4], DEEPAK[5], GAURAV SHARMA[6], MANISH KUMAR YADAV[7], SANJAY MARWAH[8]

ABSTRACT

Introduction: Chest tube placement remains amongst the most performed emergency procedure in trauma patients to drain blood or air from the pleural space. After evacuation of pleural contents, removal of chest tube is equally important since its careless removal can cause serious complications like Recurrent Pneumothorax (RP) and even lung collapse. There is no consensus in the available literature about the phase of respiration favourable for the removal of chest tube.

Aim: To compare the outcome in terms of complications like RP following chest tube removal with respect to phase of respiration in chest trauma patients and risk factors responsible for development of these complications.

Materials and Methods: The present study was a randomised controlled trial conducted at the Department of Surgery, Pt. BD Sharma Post Graduate Institute of Medical Sciences, Rohtak, India, between 1st August 2020 and 31st July 2022. Total one hundred and forty-six patients presenting in emergency with thoracic trauma requiring intercostal intubation were initially enrolled in the study; out of which 20 patients were excluded based on exclusion criteria. The remaining patients were randomised into case group (group EI) in which chest tube was removed at end of inspiration and control group (group EE) in which chest tube was removed at end of expiration with 63 patients in each group. Complications after chest tube removal were noted and possible risk factors for development of these complications were analysed.

Results: A total of 146 patients participated in the study of which the majority of the patients were male (n=54 in EE group and 58 in EI group) in both the groups and the distribution of gender in both the groups was comparable. Mean age for the patients in EE group was 38.71±15.23 years and EI group was 41.35±14.91 years and was statistically comparable. 10 (15.87%) patients in EE group and 9 (14.29%) patients in EI group developed complications and the difference was statistically not significant (p=0.803). Factors like duration between trauma and placement of chest tube, Thoracic Trauma Severity Score (TTSS), duration of intercostal drainage in situ, mechanism of injury and presence of air leak were noted however none of these factors showed statistical significance for development of complications in both the groups.

Conclusion: It is safe to remove chest tube at the end of inspiratory as well as expiratory phase of respiration without any additional risk of complications irrespective of mechanism of injury, duration of chest tube in situ, presence of air leak, duration between trauma and chest tube insertion and TTSS. However, immediate and complete sealing of the entry site after removal of chest tube helps in minimising the risk of complications.

Keywords: Intercostal tube removal, Respiratory phase, Thoracic trauma

INTRODUCTION

In thoracic trauma cases, chest tube placement remains the most performed emergency procedure to drain blood or air from the pleural space [1]. Management of chest tubes needs standard protocols or pathways but there is limited literature and evidence about the timing as well as technique of chest tube removal. Removal of chest tube is associated with multiple complications like RP, effusion or subcutaneous emphysema of which RP is the most significant complication [2-4]. These complications may lead to increased morbidity, prolonged hospital stay and economic burden for patients. So, attempts to determine optimal method of chest tube removal should be made.

Among the available literature there is no consensus about the phase of respiration favourable for the removal of thoracostomy tube and opinions are divided between removal of tube at end expiration [5,6] or end inspiration [7]. From a physiologic point of view, at the end of expiration the difference between atmospheric and pleural pressures is at its minimum, decreasing the possibility of inadvertent airflow into the pleural space when pulling out pleural tubes. However, at the end of inspiration, lungs are fully expanded and no space between parietal and visceral pleura is left, and that could also have a beneficial effect [8]. Hence, the respiratory mechanics favouring removal of chest tube at end expiration as well as end inspiration are present thereby further stressing the need to find the ideal phase of respiration for chest tube removal. Thus, the present study intended to compare (end inspiration/end expiration) the outcome following chest tube removal with phase of respiration in chest trauma. Also, potential risk factors for developing these complications following chest tube removal were assessed.

MATERIALS AND METHODS

The present study was a randomised controlled trial conducted at the Department of Surgery, Pt BD Sharma Post Graduate Institute of Medical Sciences, Rohtak, India, between 1st August 2020 to 31st July 2022 after taking approval from the institutional ethics committee (letter no. AC/PG/2021/2753). It was a parallel trial (each group receiving only one mode of intervention) and allocation ratio for both the groups was 1:1. An informed consent was taken from the participants before starting the study.

Inclusion and Exclusion criteria: Patients presenting with history of blunt or penetrating chest trauma, diagnosed with pneumothorax, haemothorax, haemopneumothorax were included in the study. However, patients with history of trauma but not associated with above mentioned findings were excluded from the study. Also, patients requiring chest tube insertion for any medical condition other than trauma, patients died or left against the medical advice during the course of treatment were excluded from the study.

Sample size calculation: The sample size in each arm was calculated according to the formula:

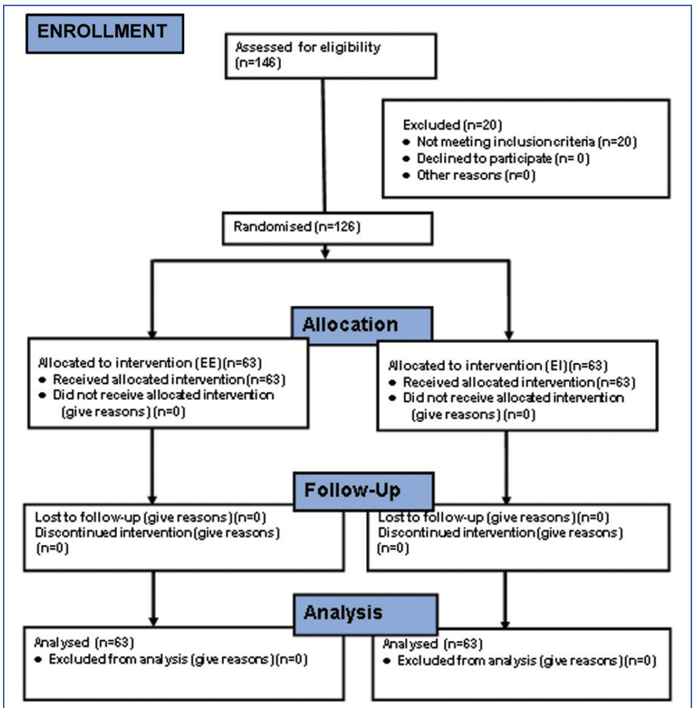
$$N= \frac{2(Z_{\alpha}+Z_{1-\beta})^2\sigma^2}{\delta^2}$$

The sample size for the study was based on a study by Bell RL et al., (2001) [8]. Taking pooled SD (σ) as 0.2, difference of means (δ) as 0.1, Type I error (α) as 5%, $Z\alpha$ as 1.96, Type II error (β) as 20%, power ($1-\beta$) as 80% and $Z1-\beta$ as 0.842 and based on the formula given above, using the mentioned values, the sample size required was:

$2\times(1.96+0.842)^2\times0.2^2/0.1^2=62.8$ (~63).

Thus, assuming 80% power and 95% confidence interval, the proposed sample size for each arm was 63 (total=126).

Total one hundred forty-six patients presenting in emergency with thoracic trauma requiring intercostal intubation were initially enrolled in the study; out of which twenty patients were excluded based on exclusion criteria [Table/Fig-1]. The remaining 126 patients were randomised into two groups of 63 each. Randomisation was done by creating two computer generated random number groups, each group containing 63 random numbers from 1 to 126 and no repetition of numbers among the two groups was ensured. One random sequence table was labelled as case group while the other was labelled as control group. Patients were enrolled in the study according to sequence number in the tables. Only participants were blinded. Case group (group EI) was one in which chest tube was removed at end of inspiration and control group (group EE) in which chest tube was removed at end of expiration.



[Table/Fig-1]: CONSORT flowchart.

Study Procedure

After initial resuscitation a detailed history was taken which included mode of injury, any comorbidities, and history of thoracic surgery. The patients were subjected to detailed clinical examination and relevant investigations like complete hemogram, arterial blood gas analysis, chest X-ray, ultrasound chest and abdomen, computed tomography scan of chest if required, and post chest tube insertion chest X-ray, biochemical investigation like blood urea, serum creatinine, random blood sugar, serum electrolytes were done.

The TTSS was calculated based on their clinical, radiological and biochemical parameters. TTSS is specific for chest trauma and includes both anatomical (involvement of lungs, pleura and ribs) as well as functional parameters (age of patient and ratio of partial pressure of oxygen in arterial blood with fraction of inspired oxygen concentration) of chest injury whereas Revised Trauma Score (RTS) and Injury Severity Score (ISS) are nonspecific scoring systems for polytrauma and takes long time to calculate [9,10]. Pape HC et al., first developed TTSS. Score for all the categories was assigned and a total score was calculated. (Minimum score for TTSS is 0 and maximum score is 25) [11]. After calculating the total score finally patients were divided into five groups. Group I includes patients with score 0-5, group II includes patients with score 6-10, group III includes score of 11-15, group IV includes score of 16-20 and group V includes score of 21-25 [12].

The decision to insert intercostal tube was based on clinical and radiological findings. The chest pain due to thoracic trauma was managed with parenteral analgesics, inter costal nerve block and epidural analgesia whenever indicated. Other associated injuries if any were managed as indicated. Chest X-ray was repeated after 3-6 hours of intercostal tube insertion to ensure the correct position of tube. The nature and volume of drainage fluid was monitored daily. The intercostal tube was removed when volume of drain output was <50ml per day as per protocols of the institute, no fresh bleed in the drainage fluid and there was no air leak within last 24 hours. Bhandari R et al., also removed chest tube at output less than 50 ml as per conventional methods [13]. The tube was removed either during end inspiratory phase or end expiratory phase based on computer generated randomised table. Two residents coordinated the procedure of chest tube removal; one resident removed the fixation suture and pulled the tube while the second resident immediately covered the wound with gauge piece and sealed with elastic adhesive tape (Dynaplast).

Chest X-ray was repeated after removal of intercostal tube. In case there was any complication following intercostal tube removal like RP, surgical emphysema, Recurrent Effusion (RE) etc., it was recorded and managed accordingly. The patient was discharged once he was free from any complication related to intercostal tube drainage. The patient was advised to follow-up in Out Patient Department (OPD) after seven and 15 days and development of any intercostal tube related complications were noted.

STATISTICAL ANALYSIS

The data was coded and entered into Microsoft Excel spreadsheet. Analysis was done using Statistical Package for Social Sciences (SPSS) version 20 (IBM SPSS Statistics Inc., Chicago, Illinois, USA) Windows software program. Descriptive statistics included computation of percentages, means and standard deviations. The data were checked for normality before statistical analysis using Shapiro-Wilk test. The unpaired t-test (for quantitative data to compare before and after observations) was applied. The Chi-square test was used for qualitative data comparison of all clinical indicators. Level of significance was set at $p\leq0.05$.

RESULTS

Majority of the patients were male (n=54 in EE group and 58 in EI group) in both the groups and the distribution of gender in both the groups was comparable. Mean age for the patients in EE group was 38.71±15.23 years and EI group was 41.35±14.91 years and was statistically comparable [Table/Fig-2]. The co-morbid factors among the two groups were statistically comparable (p-value >0.05) except for distribution of diabetes mellitus patients (p-value=0.012)

[Table/Fig-3]. No patient in either group underwent any thoracic surgery.

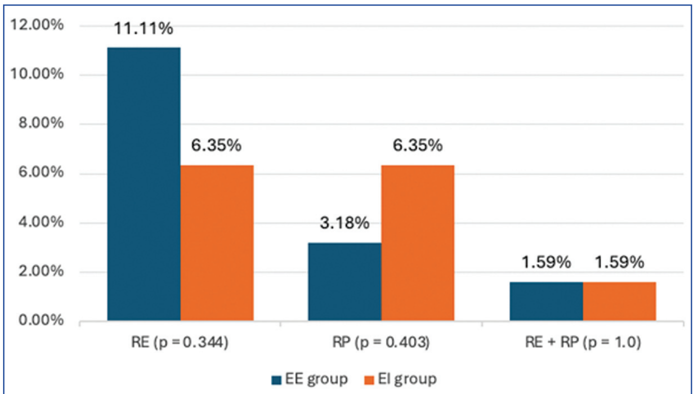
Details	EE group (n=63)	EI group (n=63)	p-value
Age (years)	38.71±15.23	41.35±14.91	0.328 (NS)
Sex (M:F)	54:9	58:5	0.257 (NS)
Mechanism of injury (B:P)	51:12	56:7	0.213 (NS)
TTSS (Mean score + SD)	5.08±1.31	5.40±1.63	0.231 (NS)
Duration between trauma and chest tube placement (hours)	29.76±82.25	18.17±24.93	0.287 (NS)
Duration of chest tube in situ (days)	4.95±2.52	5.41±2.25	0.282 (NS)
Need for mechanical ventilation	00	03	0.244 (NS)

[Table/Fig-2]: Association of demographic and clinical factors between the two groups.
NS: Not significant

Co-morbidities	Frequency	EE group	EI group	Intergroup p-value
None	99 (78.5%)	48	51	0.515
Asthma	7 (5.6%)	1	6	0.052
Hypertension	9 (7.1%)	5	4	0.729
Diabetes mellitus	6 (4.8%)	6	0	0.012
Atrial fibrillations	1 (0.8%)	1	0	0.315
History of CABG	1 (0.8%)	1	0	0.315
Pulmonary tuberculosis	3 (2.4%)	1	2	0.559
Total	126	63	63	

[Table/Fig-3]: Distribution of co-morbid factors among EE and EI group.

Overall RE, RP and both RP+RE following chest tube removal was seen in 11 (8.7%), 6 (4.8%), 2 (1.6%) patients respectively. Out of 63 patients who had chest tube removal at EE phase, 7 (11.1%) patients developed RE, 2 (3.2%) patients developed RP and 1 (1.6%) patient developed RE+RP simultaneously following chest tube removal. However, in EI group RE and RP was developed by 4 (6.35%) patients each and 1 (1.6%) patient developed RE+RP. The difference of occurrence of complications with phases of respiration was statistically non-significant (p=0.803) [Table/Fig-4].



[Table/Fig-4]: Outcome of chest tube removal with phases of respiration.

All patients in the present study belonged to TTSS group I and II. In patients belonging to TTSS group I, four patients each in both EE and EI group developed complications, whereas six patients in EE group and five patients in EI group belonging to TTSS group II developed complication. No statistically significant association was noted between TTSS and development of complications between the groups [Table/Fig-5].

Mean duration between the traumatic event and chest tube placement was 29.76±82.25 hours and 18.17±24.93 hours in patients of EE and EI group, respectively and occurrence of complications with duration between traumatic event and chest tube insertion was statistically non-significant (p-value for <24 hours

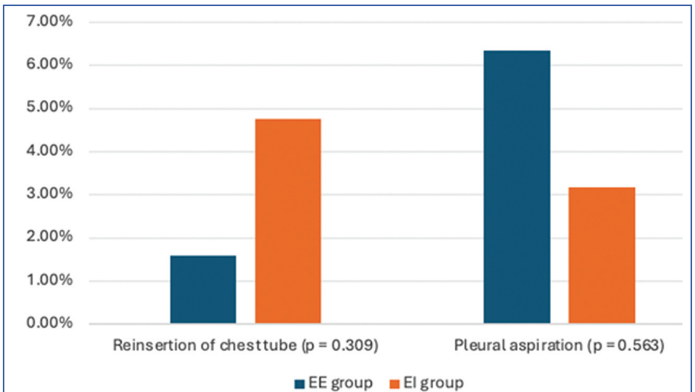
Risk factors		No. of complications/ No. of patients (EE group)	No. of complications/ No. of patients (EI group)	p-value
Duration between trauma and chest tube placement (h)	<24 h	05/54	07/57	0.563 (NS)
	>24 h	05/09	02/06	0.398 (NS)
Thoracic Trauma Severity Score (TTSS)	Group I	04/47	04/35	0.660 (NS)
	Group II	06/16	05/28	0.148 (NS)
Duration of ICD in situ (days)	<3 days	02/15	00/07	0.311 (NS)
	>3 days	08/48	09/56	0.935 (NS)
Mechanism of injury	Blunt	07/51	07/56	0.851 (NS)
	Penetrating	03/12	02/07	0.865 (NS)
Presence of air leak	--	02/09	01/04	0.913 (NS)

[Table/Fig-5]: Association of possible risk factors responsible for development of complications with respect to phases of respiration.
NS: Not significant

was 0.563 and for > 24 hours was 0.398). Chest tube in most of the patients in both EE and EI group were inserted within 72 hours, however one of the patients in EE group required chest tube insertion after 600 hours due to delayed presentation. Mean duration of keeping chest tube in situ in EE group and EI group was 4.95±2.52 days and 5.41±2.25 days, respectively and no significant difference was noted in complications developed between the two groups in terms of duration of chest tube kept in situ [Table/Fig-2,5].

Among the patients of blunt chest trauma, mode of injury was road traffic accident, fall from height and physical assault. Mode of injury among the patients of penetrating trauma was gunshot injury and stab injury to chest. Seven patients each in EE and EI group sustaining blunt trauma developed complications. Among those sustaining penetrating injury three patients in EE group and two patients in EI group developed complications. However, no difference of occurrence of complications following chest tube removal was noted with relation to mechanism of injury (p-value for blunt trauma was 0.851 and for penetrating trauma was 0.865). Out of 126 patients, 13 (10.3%) patients developed air leak following chest tube removal, out of which nine patients were from EE group and four patients were from EI group. Two patients in EE group and one patient in EI group developed RP. The incidence of RP among both the groups was also comparable (p=0.913) [Table/Fig-5].

Patients who developed complications following chest tube removal were either managed conservatively or required interventions. Chest tube reinsertion was required in 1 (1.6%) and 3 (4.8%) patients of EE and EI groups, respectively (p-value=0.309). Pleural aspiration was required in 4 (6.4%) and 2 (3.2%) patients of EE and EI groups respectively following chest tube removal (p-value=0.563) [Table/Fig-6].



[Table/Fig-6]: Association of mode of chest tube removal with requirement of chest tube reinsertion and pleural aspiration after removal of chest tube.

DISCUSSION

The aim of this study was to assess the occurrence of complications following chest tube removal with phases of respiration in thoracic trauma patients and the objective of this study was to assess incidence and potential risk factors for development of these complications. There are few studies in the literature evaluating ideal respiratory phase of chest tube removal [6-8]. Majority of the previous studies on this subject are on thoracic surgery patients [6,14].

Incidence of RP, RE and RP+RE in EE group was 3.18%, 11.11% and 1.59% whereas it was 6.35%, 6.35% and 1.59% in EI group, respectively. No statistical difference was found between both EE and EI group. Bell RL et al., recorded only RP as the outcome and reported RP in 8% and 6% cases in EI and EE groups, respectively with no statistical difference (p=1.0) between the outcome [8]. Another randomised study evaluated time and method of chest tube removal in patients requiring intercostal intubation for various indications including trauma and reported development of RP in significantly higher number of cases in end expiration without suction group (8.33%) compared to end inspiration with suction group (30.56%) with p-value of 0.013. However, overall incidence of RP after chest tube removal irrespective of application of suction was not significant (p=0.818) [7]. In contrast to this, Cerfolio RJ et al., reported significantly higher incidence of RP after removal of chest tube on full inspiration (32%) compared to full expiration (19%) with p-value of 0.007 [6] in patients undergoing elective thoracotomy. Certain factors like Valsalva maneuver, swift removal of tube followed by immediate occlusion of the insertion site are important for preventing recurrence of pneumothorax irrespective of phase of respiration [8].

Decision for chest tube reinsertion after development of RP depends on the thickness of pneumothorax on chest X-ray and patient's respiratory status. The smaller pneumothorax (<20%) can be managed with conservative management like oxygen inhalation and observation with serial chest X-ray while large pneumothorax (>20%) needs reinsertion of chest tube [7]. Total four patients in the present study (one in EE and three in EI group) needed reinsertion of chest tube and the difference was not statistically significant. Cobanoglu U et al., and Bell RL et al., also noted no significant difference in need of intervention for RP between EE and EI group [Table/Fig-7] [6-8]. In the present study, incidence of RE following chest tube removal has been analysed and its occurrence does not have any association with tube removal with respect to the phase of respiration, however this has not been studied in past by anyone.

at the time of discontinuation of chest tube [7,8]. However, there is lack of agreement over the volume of chest tube drainage at the time of removal of chest drain. Reports favouring removal of chest tube at drainage volume as high as 450 ml [6] are there however in the present study chest tubes were removed when serous drainage output was <50 mL in 24 hours. On basis of duration of chest tube in situ, occurrence of RP following chest tube removal was almost comparable between both EE and EI groups in present as well as Bell RL et al., study [8].

Characterisation of injury severity is crucial for scientific study in trauma patients. Bell RL et al., used RTS and ISS for calculation of injury severity in thoracic trauma patients [8]. In the present study instead of RTS and ISS TTSS was used for calculation of thoracic trauma severity that includes both anatomical and functional parameters. The occurrence of RP was comparable among the two groups when compared with relation to trauma severity score in the present study (p-value >0.05). Bell RL et al., noted the similar findings using RTS and ISS [8].

Chest trauma can be either due to blunt or penetrating mechanism. In the present study, majority of the patients requiring chest tube insertion sustained blunt thoracic trauma (84.9%). Similarly, Martin M et al., reported that 86.6% of the patients required insertion of thoracostomy tube for blunt trauma [16]. However, Bell RL et al., reported gunshot wound as the most common mechanism of penetrating thoracic trauma [8]. Based on mechanism of trauma the difference in occurrence of RP following chest tube removal irrespective of phase of respiration was statistically non-significant in present as well as Bell RL et al., study [8].

Most accepted method in presence of air leak is to keep the chest tube in situ till the air leak resolves, however there is still lack of consensus regarding the timing of removal of chest tube in terms of drain output and phase of respiration [17]. In the present study, on absence of air leak for 24 hours, the chest tube was clamped for six hours and tube was removed only if there was no RP on chest X-ray. Association between presence of air leak and occurrence of RP following chest tube removal was comparable among both groups. However, as per our knowledge no other study in past has compared this parameter among two groups. Traditional method of determining air leak is by observing of air bubbles in the water seal. Disadvantage of this traditional analogue system is that it can't provide information about the amount and patterns of air leak,

Study	Place and year of study	Sample size	Indication for chest tube insertion	Intervention required in EE group (N%)	Intervention required in EI group (N%)	p-value
Present study	India (2020-2022)	126 patients (63 in each group)	Trauma	1.59%	4.76%	0.309 (NS)
Bell RL et al., [8]	United States (2000)	102 tubes in 69 patients (52 EI and 50 EE group)	Trauma	2%	4%	1.0 (NS)
Cerfolio RJ et al., [6]	England (2008-2011)	342 patients (179 EI and 163 EE group)	Elective thoracotomy for pulmonary resection	1%	3%	0.310 (NS)
Cobanoglu U et al., [7]	Turkey (2005-2008)	144 patients (72 in each group)	Thoracic trauma, thoracotomy, empyema etc.	23.07% of patients required reinsertion of chest tube irrespective of phase of respiration at time of chest tube removal		

[Table/Fig-7]: Table showing comparisons of various studies requiring intervention for significant Recurrent Pneumothorax (RP) [6-8].
NS: Not significant

First sixty minutes after trauma is critically important for positive treatment outcome and is termed as "Golden hour of trauma" [15]. The time lag between chest trauma and chest tube insertion has not been studied in past. In the present study, all the patients had chest tube placement after golden hour due to time taken in transportation of the trauma patients from accident site to our institute. However, based on duration between trauma and chest tube insertion, the difference in occurrence of complications following chest tube removal was statistically non-significant between the two groups.

There is lack of consensus on the time of chest tube removal. Most of the studies agree that there should be either no or a small but stable pneumothorax and absence of air leak for at least 24 hours

and hence may lead to early or delayed removal of chest drain. This problem can be dealt with use of digital drainage systems which can provide quantitative information on air leak as well as its patterns [18].

There is scanty literature available to study the impact of positive pressure ventilation during chest tube in situ on outcome following chest tube removal. In the present study, three out of 126 patients (2.4%) required ventilatory support and chest tube was removed only when patients were off the ventilatory support. None of the patients of either group developed RP following chest tube removal. In the study of Bell RL et al., 15 out of 69 patients (21.7%) requiring ventilatory support also had similar results [8]. One study has also shown that the incidence of RP following chest tube removal is 12% if chest tube is removed while patient is on ventilatory support [19]. Thus, positive pressure ventilation does not have any influence on occurrence of RP following chest tube removal provided that the chest tube is removed once patient is off the ventilatory support.

Merit of the study is that it is a prospective randomised control study that included only emergency patients undergoing chest tube insertion for thoracic trauma and there is only one study of this kind in the available literature. TTSS was included in this study; no other study has assessed its association with outcome following chest tube removal. In cases of thoracic trauma with chest tube insertion, many factors (viz., duration between chest trauma and chest tube placement, presence of air leak during chest tube in situ) have been evaluated for association with occurrence of RP following chest tube removal. These factors have never been evaluated earlier in such cases as per available literature.

Limitation(s)

Limitation of the study is that air leaks were subjective to the observation of physician, however more accurate methods like digital systems to assess the air leak can be used that were not available in our set up.

CONCLUSION(S)

The occurrence of RP following chest tube removal and its relation with two phases of respiration has not been explored much in the past. Although the routine practice is to remove the chest tube at the end of expiration but based on the results of present study, it can be concluded that it is equally safe to remove chest tube at the end of inspiration without significant increase in the rate of complications. These findings include patients of thoracic trauma only, however to widen the spectrum and to generalise the results, a study including various other indications of chest drainage should be conducted on a larger magnitude

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PARTICULARS OF CONTRIBUTORS:

1. Assistant Professor, Department of Surgery, PT. BD Sharma, PGIMS, Rohtak, Haryana, India.
2. Senior Resident, Department of Urology, Sir Ganga Ram Hospital, Delhi, India.
3. Professor, Department of Surgery, PT. BD Sharma, PGIMS, Rohtak, Haryana, India.
4. Senior Resident, Department of Surgery, PT. BD Sharma, PGIMS, Rohtak, Haryana, India.
5. Junior Resident, Department of Surgery, PT. BD Sharma, PGIMS, Rohtak, Haryana, India.
6. Junior Resident, Department of Surgery, PT. BD Sharma, PGIMS, Rohtak, Haryana, India.
7. Junior Resident, Department of Surgery, PT. BD Sharma, PGIMS, Rohtak, Haryana, India.
8. Senior Professor, Department of Surgery, PT. BD Sharma, PGIMS, Rohtak, Haryana, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Sanjay Marwah,
Senior Professor, Department of Surgery, PT. BD Sharma, PGIMS, Rohtak,
Haryana, India.
E-mail: drsanjay.marwah@gmail.com

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- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. NA

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