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TENSION PNEUMOTHORAX PATHOPHYSIOLOGY AND CLINICAL SIGNS IN PATIENTS WITH COMORBIDITIES A SYSTEMATIC REVIEW

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Abstract:

Background: *Health care providers uses classically described signs and symptoms to diagnose tension pneumothorax, available literature sources differ in their descriptions of its clinical manifestations. Moreover, while the clinical manifestations of tension pneumothorax have been suggested to differ among subjects of varying respiratory status, it remains unknown if these differences are supported by clinical evidence. Thus, the primary objective of this study is to systematically describe and contrast the clinical manifestations of tension pneumothorax among patients receiving positive pressure ventilation versus those who are breathing unassisted.*

Methods: *We used search electronic bibliographic databases (MEDLINE, PubMed, EMBASE, and the Cochrane Database of Systematic Reviews) and clinical trial registries from their first available date as well as personal files, identified review articles, and included article bibliographies. Two investigators will independently screen identified article titles and abstracts and select observational (cohort, case-control, and cross-sectional) studies and case reports and series that report original data on clinical manifestations of tension pneumothorax. These investigators will also independently assess risk of bias and extract data. Identified data on the clinical manifestations of tension pneumothorax will be stratified according to whether adult or pediatric study patients were receiving positive pressure ventilation or were breathing unassisted, as well as whether the two investigators independently agreed that the clinical condition of the study patient(s) aligned with a previously published tension pneumothorax working definition. These data will then be summarized using a formal narrative synthesis alongside a meta-analysis of observational studies and then case reports and series where possible. Pooled or combined estimates of the occurrence rate of clinical manifestations will be calculated using random effects models (for observational studies) and generalized estimating equations adjusted for reported potential confounding factors (for case reports and series).*

Conclusion: *This study will compile the world literature on tension pneumothorax and provide the first systematic description of the clinical manifestations of the disorder according to presenting patient respiratory status. It will also demonstrate a series of methods that may be used to address difficulties likely to be encountered during the conduct of a meta-analysis of data contained in published case reports and series*

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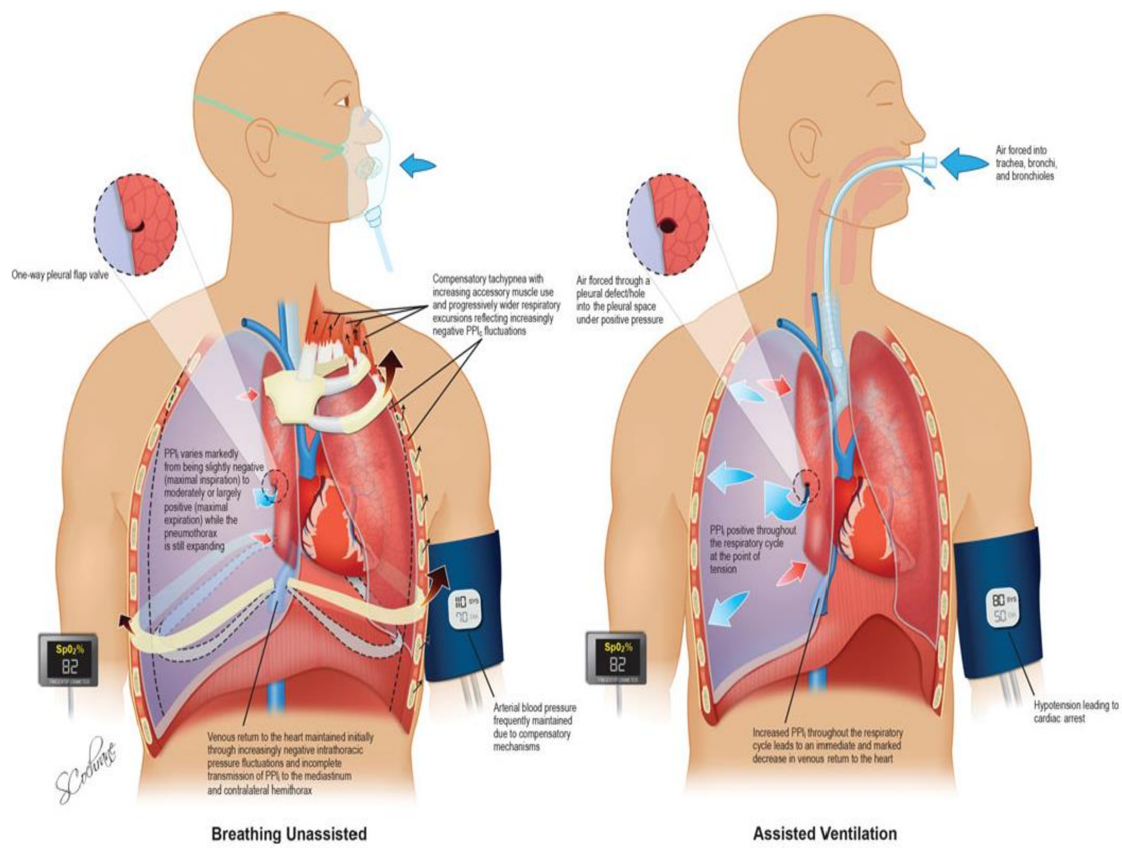
INTRODUCTION:

Tension pneumothorax is an uncommon condition with a high mortality rate most frequently reported to occur in prehospital, emergency department, and intensive care unit (ICU) settings[1–4]. This condition is frequently lethal in injured and ventilated ICU patients without early diagnosis and treatment.5–7 Although the incidence of tension pneumothorax remains poorly estimated, it may occur in up to 1% to 3% of prehospital, major trauma and ICU patients[1,3,8–12]. As many authorities recommend urgent thoracic decompression when the diagnosis is first suspected, health care providers are taught to search for classically described clinical manifestations to recognize patients who may have tension pneumothorax [5,6,13]. Although tension pneumothorax is therefore a syndrome diagnosis, available literature sources differ substantially in their descriptions of its clinical presentation [1]. Many of these have been generalized from canine studies of the disorder[14,15] and do not account for potential differences in pathophysiology and physical signs based on the ventilatory status of the patient (Fig. 1)[1,6,16–21] As misdiagnosis or inappropriate treatment of tension pneumothorax can have devastating consequences [6,22–26] a comprehensive description of its clinical presentation may improve patient care.1 Thus, we conducted a systematic review to determine whether the reported clinical presentation (and resultant management and outcomes) of tension pneumothorax differs between patients who are breathing unassisted (ie, breathing spontaneously and not receiving positive pressure ventilation) versus receiving assisted (ie, positive pressure) ventilation. Our primary objective was to determine whether available clinical data support animal study observations of potentially important differences between subjects of varying ventilatory status in time to, severity, and frequency of presenting hemodynamic complications [16,17,19]. As systematic reviews of case reports and series of other uncommon/emergent conditions have guided clinical practice and future research,27–31 we synthesized and analyzed data reported by these types of studies alongside a systematic review of observational studies[1,32–35].



Trials .com). We also used the PubMed "related articles" and Google Scholar "cited by" features and manually searched reference lists of included articles and relevant review papers identified during the search.

Study Selection

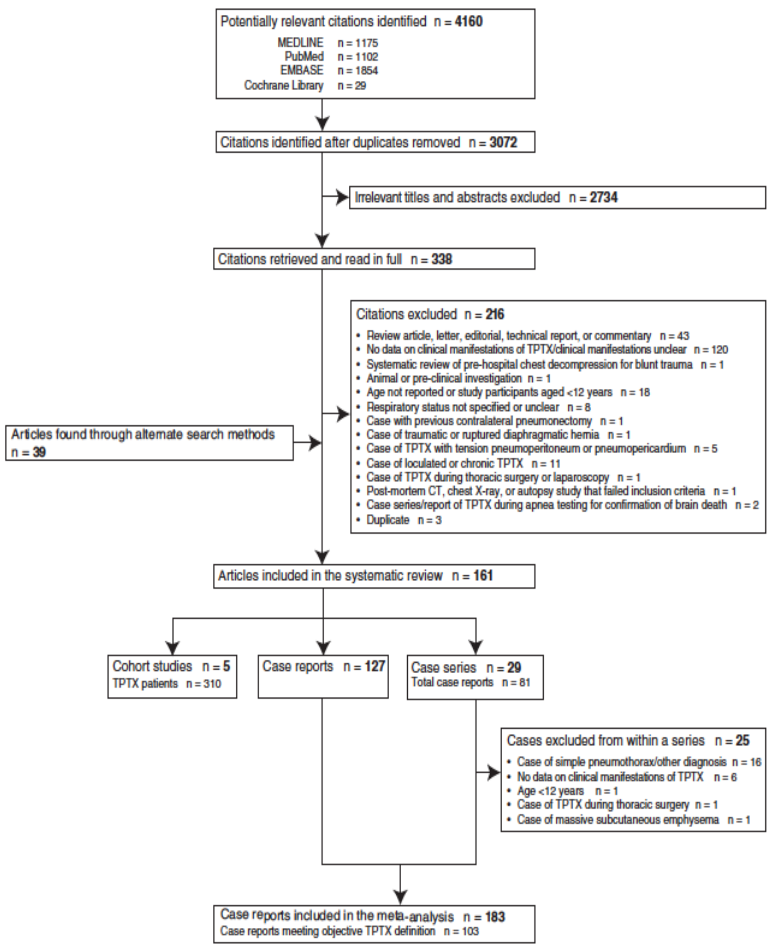
Two physicians (D.J.R. and C.B.) independently reviewed titles and abstracts of citations identified by the search and selected articles for full-text review. Potentially relevant non-English language articles were translated into English.We included observational (cohort, casecontrol, and cross-sectional) studies and case reports and series38,39 that reported original data on clinical manifestations of tension

METHODS:

A published protocol details our study methods [1]. This protocol was registered in the PROSPERO Register of Systematic Reviews and developed according to recommendations for conducting systematic reviews and metaanalyses.

Data Sources

With assistance from a medical librarian (H.L.R.), we searched Ovid MEDLINE and EMBASE, PubMed, and the Cochrane Library from their first available dates to October 15, 2013 without restrictions (see our protocol1 for details regarding database search strategies). To identify additional/ongoing studies, we searched personal files, wrote to colleagues and content experts, and investigated 2 clinical trials registries (ClinicalTrials.gov and www.Controlled-



Pneumothorax. We defined clinical manifestations as patient-level findings gathered during medical interview, physical examination, or through invasive monitoring or treatment equipment or diagnostic studies [1,40]. Studies and reports of fatal cases were included if the condition causing death was attributed by authors to be tension pneumothorax and associated with expulsion of air on thoracic decompression or determined by a pathologist to be present on autopsy [1]. We excluded studies and reports not describing patient ventilatory status and those involving children (defined as age <12 years41), as their clinical presentation likely differs from older patients because their mediastinum and thoracic wall are more compliant [1,15,16]. We also excluded studies and reports involving patients with conditions that could misrepresent the more common clinical manifestations of tension pneumothorax.1 Disagreements regarding study eligibility were resolved by discussion after the entire article had been reread in full. Inter investigator agreement was quantified using kappa (κ) statistics,42 and the κ-statistic interpretation guidelines suggested by Altman [43].

Data Extraction

Two physicians (D.J.R. and C.B.) independently extracted data from included studies and case reports using a data extraction spreadsheet.1 Data extracted included study and case characteristics and reported clinical manifestations, initial management, and outcomes of tension pneumothorax.1 For case reports, the 2 physicians independently categorized times from onset of symptoms, a deterioration in clinical status, or iatrogenic production of a pneumothorax to respiratory decompensation/arrest or hypotension/cardiac arrest according to whether they were described to occur suddenly (approximately0 to 5 minutes), acutely (approximately >5 to 60 minutes), subacutely (approximately >60 to 180 minutes), or in a more delayed fashion (approximately >180 minutes). Clinical manifestations data were abstracted as proximal as possible to author's descriptions of pretreatment diagnoses of tension pneumothorax.When partial pressure of arterial oxygen (PaO_2) and fraction of inspired oxygen (FiO_2) values were not provided, these were estimated from reported arterial oxygen saturation (SpO_2) values and oxygen delivery device flow rates using conversion tables [44].

Risk of Bias Assessment

For observational studies, 2 physicians (D.J.R. and C.B.) independently evaluated whether tension pneumothorax diagnoses were supported by radiographic findings/response to thoracic decompressionand whether overlap existed between diagnostic criteria and reported clinical manifestations [1]. They also evaluated settings from which patients were recruited to determine whether they were likely representative of the population of tension pneumothorax patients [1]. Finally, they assessed whether reported frequencies of clinical manifestations were precise [(by assessing widths of associated confidence intervals (CIs)] and whether clinical manifestations were sought thoroughly and consistently (by determining methods by which they were gathered and whether this was done similarly across all study patients).1 For case reports, the 2 physicians independently determined whether patient presentations satisfied a published tension pneumothorax definition [1]. According to this definition, a tension pneumothorax was defined as one "that results in significant respiratory or hemodynamic compromise that reverses (or at least significantly improves) on thoracic decompression alone [1,6].

Observational Study Data Synthesis

As included observational studies were limited by clinical heterogeneity, planned observational study meta-analyses1 were not conducted. Results of these studies were instead described narratively. Exact, 95% CIs surrounding dichotomous clinical manifestations variables reported by observational studies were determined using the Clopper-Pearson method [45].

Case Reports and Series Data Synthesis and Analysis

We summarized characteristics of reported cases and their described clinical manifestations, management, and outcomes as proportions, medians (with interquartile ranges), and means (with standard deviations). Dichotomous and continuous variables were compared using Fisher exact and Wilcoxon rank sum or matched-pairs signed-ranks tests, respectively. We estimated unadjusted and adjusted mean differences and odds ratios (ORs) comparing hemodynamic events at tension pneumothorax diagnosis between cases who were breathing unassisted and receiving assisted ventilation. To accommodate for clustering of clinical manifestation variables in case series, we conducted these comparisons using generalized estimating equations with independent correlational data structures.46 Model covariates for adjusted analyses included age; antihypertensive or vasopressor administration before diagnosis; preexisting shock; history of hypertension, heart failure, or pulmonary disease; and concomitant diagnosis of hemothorax, other pleural effusion, or new pulmonary disease.1 A separate clustered logistic regression model was used to determine whether subcutaneous emphysema, tracheal deviation, jugular venous distention, ipsilateral percussion hyperresonance, hypoxia, hypotension, respiratory arrest, or cardiac arrest independently predicted ventilatory status across included case reports.

To test the robustness of our findings, we conducted sensitivity analyses in which we recalculated the aforementioned comparisons using only those cases that satisfied the published tension pneumothorax definition [6] we also explored whether adjusted ORs varied in magnitude or direction among subgroups of cases.1 We considered2-sided P values of less than 0.05 significant. Stata MP version 13.1 (Stata Corp., College Station, TX) was used for statistical analyses.

RESULTS:

Study Selection

Among 4160 citations identified by the search, we included 5 cohort studies (n = 310 total patients),12,47–50 29 case series (median, 2 cases per series; range, 1–5), and 127 case reports in the systematic review. Inter-investigator agreement on full-text article inclusion was good (κ-statistic, 0.75; 95% CI, 0.68–0.82). We requested supplementary information on study procedures or reported cases from 11 authors, and 10 responded [3,11,12,48,51–56]. After excluding 25 cases that failed inclusion criteria from within included case series, 183 cases were included in the synthesis and analysis of case reports and series data.

Description of Included Cohort Studies and Case Reports:

Characteristics of included cohort studies are presented in Table 1. Studies were published between 2005 and 2014. Three exclusively enrolled prehospital trauma patients treated with needle thoracostomy for suspected tension pneumothoraces [12,48,50] 1 included only injured patients who received prehospital tube thoracostomy,49 and 1 enrolled ICU patients with both ventilator-associated simple and tension pneumothoraces.47 Mean patient ages ranged from31.5 to 67 years. Three studies included patients receiving assisted ventilation,47–49 whereas only 1 reported separately on patients who were breathing unassisted versus receiving assisted ventilation.50 The fifth study included 2 groups of patients of which 61% and 87% were receiving assisted ventilation.12 Among the 183 included cases, 86 (47.0%) were breathing unassisted and 97 (53.0%) receiving assisted ventilation (see Table in Supplemental Digital Content 1, available at http://links. lww.com/SLA/A690, for details regarding case ventilatory statuses). Most (75.4%) cases were reported after the year 1990. The proportion of reported cases who were breathing unassisted increased across the study search period from a minority of the total reports before 1994 to the majority of them thereafter (see Figure in Supplemental Digital Content 2, available at http://links.lww.com/SLA/A691). The Table in Supplemental Digital Content 3, available at http://links.lww.com/SLA/A692, provides a bibliography of included case reports/series and characteristics of individual cases. The demographics and medical history of cases were similar between ventilatory status groups (Tabl. Mean age of all cases was 45.5 years (standard deviation, 20.2 years). A total of 3.5% of cases who were breathing unassisted received general anesthesia before diagnosis versus 55.7% receiving assisted ventilation. Bilateral tension pneumothoraces were less frequent among cases breathing unassisted (2.3%) versus receiving assisted ventilation (24.4%).

Trauma was a relatively commonly reported cause of tension pneumothorax among all cases (Table 2). However, spontaneous pneumothoraces and gastrointestinal perforation were more frequently described etiologies among cases breathing unassisted whereas barotrauma and attempted central venous catheter insertions were more commonly reported causes among cases receiving assisted ventilation.

Risk of Bias Assessment

An overview of the risk of bias of included cohort studies is shown in Table 3. In all studies, tension pneumothorax diagnoseswere partly supported by diagnostic imaging findings and/or the cardiorespiratory response of the patient to thoracic decompression. Described patient presentations or case definitions partly satisfied the published tension pneumothorax definition in 3 cohort studies.48–50 One study combined some data on clinical manifestations of simple and tension pneumothoraces together [49]. The 2 physicians independently agreed that clinical conditions of 103 (57.2%) included cases satisfied the published tension pneumothorax definition (κ-statistic, 0.89; 95% CI, 0.82–0.95). Characteristics of these cases were similar when compared with all cases (see Table in Supplemental Digital Content 4, available at http://links.lww.com/SLA/A693). Reported Clinical Presentation of Tension Pneumothorax.

Signs and Symptoms

Signs and symptoms of tension pneumothorax reported by included cohort studies and case reports, respectively.

Signs and symptoms reported by all included case

reports were similar to those that satisfied the published tension pneumothorax
definition (see Table in Supplemental Digital Content 5, available at http://links.lww.com/SLA/A694).

Symptoms and Respiratory Vital Signs

Symptoms reported among case reports of patients breathing unassisted included chest pain (52.3%), dyspnea (38.4%), and shortness of breath (31.4%). Respiratory distress was described in41.9% of cases breathing unassisted versus 8.3% receiving assisted ventilation.

Many (46.5%) case reports of patients breathing unassisted described tachypnea. Hypoxia or requirement for supplemental oxygen was reported among 43 (50.0%) cases who were breathing unassisted versus 89 (91.8%) receiving assisted ventilation (P<0.001).Hypoxia was also reported among 25.0% of patients breathing unassisted versus11.1% to 50.9% receiving assisted ventilation across 2 included cohort studies.49,50 The median PaO2/FIO2 ratio among all included case reports was 73.0 (interquartile range, 48.4–152.6). One included cohort study of mechanically ventilated patients with tension pneumothoraces reported a mean PaO2/FIO2 ratio of 150.47 Respiratory arrest occurred in 9.3% of case reports of patients breathing unassisted.

Head and Chest Examination

Jugular venous distention (7.1%) and contralateral tracheal deviation (9.3%)were uncommonly reported by included case reports and were not described by any of the included cohort studies. As compared with cases who were breathing unassisted, subcutaneous emphysema was noted more often (10.5% vs 30.9%; P = 0.001) and contralateral tracheal deviation was noted less often (17.9% vs2.9%; P = 0.004) among cases receiving assisted ventilation. In one included cohort study, subcutaneous emphysemawas reported among27.3% of patients receiving assisted ventilation.49 Ipsilateral decreased air entry, percussion hyperresonance, and decreased thoracic excursions/mobility were the most commonly reported chest examination findings among case reports of unilateral tension pneumothoraces. Ipsilateral decreased air entry was also reported among 50.0% to 54.5% of patients receiving assisted ventilation across 2 included cohort studies.48,49 Hyperresonance to percussion was more commonly described among case reports of patients breathing unassisted versus receiving assisted ventilation (26.7% vs8.3%; P = 0.001).

Cardiovascular Vital Signs

Unadjusted systolic, diastolic, and mean arterial blood pressureswere substantially higher among caseswhowere breathing unassisted versus receiving assisted ventilation. After adjustment, caseswhowere breathing unassisted had higher reported systolic (126 mm Hg vs 94 mm Hg; difference = 32 mm Hg; 95% CI, 19.8–45.0 mmHg; P<0.001) andmean arterial blood pressures (95.0mmHg vs62.8 mm Hg; difference = 32.8 mm Hg; 95% CI, 22.0–43.7 mm Hg; P < 0.001) than those receiving assisted ventilation. Moreover, when compared with cases who were breathing unassisted, the adjusted odds of hypotension (defined a priori as a mean arterial pressure≤60 mm Hg1) and cardiac arrest were 12.6 (95% CI, 5.8–27.5) and17.7 (95% CI, 4.0–78.4) times higher among those receiving assisted ventilation, with the most commonly reported initial arrest rhythm being pulseless electrical activity (75.0%). These increased oddswere robust to a number of sensitivity analyses (see Table in Supplemental Digital Content 6, available at http://links.lww.com/SLA/A695). One included cohort study also reported that none of the included patients with a tension pneumothorax who were breathing unassisted versus39.6% of those receiving assisted ventilation presented without an arterial pulse.50 Clustered logistic regression suggested that contralateral tracheal deviation was independently associated with an increased odds of breathing unassisted (OR, 33.3; 95% CI, 3.0–364.5; P = 0.004) whereas hypotension (OR, 8.6; 95% CI, 3.5–31.5; P < 0.001) and subcutaneous emphysema (OR, 5.9; 95% CI, 1.9–18.4; P = 0.002) were independently associated with an increased odds of having received assisted ventilation.

Disease Evolution

Approximate times to development of hypotension/cardiac arrest could be determined for 20 (90.9%) case reports of patients breathing unassisted versus 54 (72.0%) receiving assisted ventilation. In contrast to cases who were breathing unassisted, the majority (70.4%) of those receiving assisted ventilation who experienced hypotension or cardiac arrest developed these signs within minutes of clinical presentation.

Initial Investigations

A chest radiograph was obtained before treatment in 55(64.0%) case reports of patientswhowere breathing unassisted versus44 (45.4%) receiving assisted ventilation. A pneumothorax occupying greater than 50% of hemithorax volume (55.8%), contralateral

DISCUSSION:

In this systematic review, after considering findings of animal studies of tension pneumothorax,14–17,19–

21 we synthesized information on the clinical presentation of patients with tension pneumotho-FIGURE 4. Percentage of case reports of patients with tension pneumothorax who presented with sudden, acute, subacute, and delayed hypotension or cardiac arrest. Sudden was defined as approximately 0 to 5 minutes, acute as more than 5 to60 minutes, subacute as more than 60 to 180 minutes, and delayed as more than 180 minutes. rax reported by 5 cohort studies and 183 case reports (n=86 breathing unassisted, n = 97 receiving assisted ventilation).When summarized, these studies highlight a number of reported differences in clinical presentation depending on the ventilatory status of the patient see Table 5 for a summary). They also highlight how clinicians reportedly diagnose and manage these patients in practice. Cases who were breathing unassisted were frequently reported to present with shortness of breath, dyspnea, tachypnea, respiratory distress, hypoxemia, and ipsilateral decreased air entry and percussion hyperresonance. Pulmonary dysfunction progressed to respiratory arrest in 9% of cases breathing unassisted. Hypotension and cardiac arrest were reported among only 16% and 2% of included cases who were breathing unassisted, respectively, and among none of the 12 breathing unassisted patients in one included cohort study.50 When these outcomes did occur, more than half of the cases seemed to develop them in a relatively delayed fashion, and nearly two-thirds of clinicians obtained a chest radiograph before performing thoracic decompression. Despite this, half of the cases were managed first with needle thoracostomy. Hypoxemia, subcutaneous emphysema, and ipsilateral decreased air entry were also commonly described among case reports and cohort studies of patients receiving assisted ventilation. However, the clinical presentation of these patients differed substantially from those who were breathing unassisted, potentially as a result of their requirement for ventilatory support and/or greater illness severity. Similar to animal study findings (Fig. 1), when compared with case reports of patients who were breathing unassisted, hypotension and cardiac arrest were significantly more commonly reported to be present at the time of tension pneumothorax diagnosis. These outcomes were also frequently described to occur within minutes of a sudden clinical deterioration (eg, a decrease in SpO2) or an iatrogenic creation of a pneumothorax. Interestingly, however, half of the cases receiving assisted ventilation underwent chest radiography before thoracic decompression and half were initially managed with tube thoracostomy. Our findings may have implications for improving the diagnosis and treatment of tension pneumothorax. In contrast to classical medical teaching, contralateral tracheal deviation and jugular venous distention are uncommonly reported clinical manifestations of tension pneumothorax.

Tension pneumothorax may have to be considered in patients who are breathing unassisted who present with predominantly respiratory signs and symptoms. As those who are breathing unassisted have seldom been reported to present with sudden hemodynamic compromise, it may be appropriate to obtain a chest radiograph in a monitored setting to confirm the diagnosis and lateralize the disease instead of performing urgent thoracic decompression for patients who are not in extremis [5,6,13]. Thoracic ultrasonography may be superior to chest radiography for this purpose, as it has a sensitivity of approximately 80% to 90% for detection of pneumothoraces (versus approximately 50% for supine chest radiography) and can be performed rapidly at the bedside.57,58 Conversely, clinicians should be prepared to perform urgent thoracic decompression without chest radiographic confirmation in patients suspected of a tension pneumothorax who are receiving assisted ventilation, as these patients have frequently been reported to present with sudden hemodynamic compromise and/or cardiac arrest. Our synthesis and analysis of case reports/series data has several potential limitations. Our estimates of the frequency of clinical manifestations of tension pneumothorax may have been influenced by underreporting of relatively common presentations of tension pneumothorax or overreporting of presentations that manifested more unusual or interesting clinical features.1,59 However, as we can think of no reason why under- or overreporting would depend on case ventilatory status, it seems unlikely that selection bias would have influenced our between-group comparisons. Furthermore, although some of the included case reports could be argued not to represent tension pneumothorax, our findings were robust to sensitivity analyses that included only cases satisfying a published definition. Similarly, as we included case reports of patients with less common etiologies of tension pneumothorax (eg, gastrointestinal perforation), the validity of combining all cases together may be questioned.1 Despite this, we are unsure why patients with a less common etiology would present with different clinical manifestations when compared to those with more common etiologies [1,16,17,19–21]. Finally, although some may argue that our findings may be due to unmeasured confounding [59], this seems unlikely given that any unmeasured confounder that could account for the observed magnitude of the association between ventilatory status and hypotension/cardiac arrest would have to be very strongly associated with patient ventilatory status and highly predictive of hypotension and cardiac arrest. Thus, as our findings are consistent with results from animal studies [16,17,19–21] we believe them to be clinically important.

CONCLUSIONS:

The reported clinical presentation of tension pneumothorax depends on the ventilatory status of the patient. This may have implications for improving the diagnosis and treatment of this uncommon yet catastrophic clinical condition.

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