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Tube thoracostomy versus conservative management for acute spontaneous pneumothorax

Akut spontan pnömotoraks için konservatif tedaviye karşı tüp torakostomi: Sistematik kanıt sentezi ve klinik sonuçlar analizi

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ABSTRACT

To evaluate the clinical efficacy and safety of emergency department tube thoracostomy compared to conservative or elective treatment strategies in patients with acute spontaneous pneumothorax.

Comprehensive systematic search of PubMed, Web of Science, and Scopus databases was conducted for publications between 2014 and 2024. Seventy-seven studies involving 12,847 patients were included in the analysis following PRISMA 2020 guidelines. Statistical analysis was performed using RevMan 5.4, R, and Stata software. Evidence quality was assessed using GRADE methodology. Risk ratios (RR) with 95% confidence intervals (CI) were calculated for binary outcomes.

Emergency department tube thoracostomy demonstrated significantly higher treatment success compared to conservative or elective management [RR: 1.34 (95% CI: 1.18-1.52), p<0.001]. However, no significant difference was observed in recurrence rates between groups [RR: 1.13 (95% CI: 0.94-1.35), p=0.198]. Hospital length of stay was comparable between groups (standardized mean difference: 0.21, p=0.098). Complication rates were significantly higher in the intervention group [RR: 1.27 (95% CI: 1.04-1.55), p=0.024], while mortality rates did not differ significantly [RR: 1.88 (95% CI: 0.41-8.61), p=0.410]. Moderate quality evidence was identified for all primary outcomes.

In conclusion, Although emergency department tube thoracostomy improves short-term treatment success in acute spontaneous pneumothorax, it does not provide distinct advantages regarding long-term recurrence rates. Treatment decisions should be individualized, considering patient comorbidities, socioeconomic status, follow-up capacity, and patient preferences. Evidence-based clinical algorithms integrating patient-specific factors are recommended for optimal treatment selection in acute pneumothorax management.

Keywords: Spontaneous pneumothorax; tube thoracostomy; emergency management; clinical outcomes; management strategies.

ÖZET

Akut spontan pnömotoraksı olan hastalarda acil servis tüp torakostomisinin konservatif veya elektif tedavi stratejilerine kıyasla klinik etkinliğini ve güvenliğini değerlendirmek amaçlanmıştır.

2014-2024 yılları arasında yayınlanan makaleler için PubMed, Web of Science ve Scopus veritabanlarında kapsamlı bir sistematik arama yapıldı. PRISMA 2020 kılavuzlarına göre 12.847 hastayı içeren 77 çalışma analize dahil edildi. İstatistiksel analiz RevMan 5.4, R ve Stata yazılımları kullanılarak gerçekleştirildi. Kanıt kalitesi GRADE metodolojisi kullanılarak değerlendirildi. İkili sonuçlar için %95 güven aralığı (CI) ile risk oranları (RR) hesaplandı.

Acil servis tüp torakostomisi, konservatif veya elektif yönetime kıyasla anlamlı derecede daha yüksek tedavi başarısı gösterdi (RR: 1,34 (%95 CI: 1,18-1,52), p<0,001). Ancak, gruplar arasında tekrarlama oranlarında anlamlı bir fark gözlenmedi (RR: 1,13 (95% CI: 0,94-1,35), p=0,198). Hastanede kalış süresi gruplar arasında karşılaştırılabilir düzeydeydi (standartlaştırılmış ortalama fark: 0,21, p=0,098). Komplikasyon oranları müdahale grubunda anlamlı derecede daha yüksekti (RR: 1,27 (95% CI: 1,04-1,55), p=0,024), ölüm oranlarında ise anlamlı bir fark yoktu (RR: 1,88 (95% CI: 0,41-8,61), p=0,410). Tüm birincil sonuçlar için orta düzeyde kanıt kalitesi belirlendi.

Acil serviste tüp torakostomi, akut spontan pnömotoraks tedavisinde kısa vadeli başarıyı artırsa da, uzun vadeli tekrarlama oranları açısından belirgin bir avantaj sağlamamaktadır. Tedavi kararları, hastanın eşlik eden hastalıkları, sosyoekonomik durumu, takip kapasitesi ve hasta tercihleri dikkate alınarak bireyselleştirilmelidir. Akut pnömotoraks yönetiminde optimal tedavi seçimi için hastaya özgü faktörleri entegre eden kanıta dayalı klinik algoritmalar önerilmektedir.

Anahtar kelimeler: Spontan pnömothorax; tüp torakostomi; acil durum yönetimi; klinik sonuçlar; akut spontan pnömothorax.

INTRODUCTION

Spontaneous pneumothorax, defined as the acute collapse of lung tissue without traumatic etiology, represents a significant clinical challenge in emergency medicine and thoracic practice (1,2). Epidemiological data indicate that the estimated annual incidence of spontaneous pneumothorax ranges from 7.4 to 18 cases per 100,000 persons, demonstrating considerable geographic and demographic variation (3). Primary spontaneous pneumothorax typically occurs in young, otherwise healthy individuals aged 20-40 years, whereas secondary spontaneous pneumothorax is associated with underlying chronic pulmonary diseases including chronic obstructive pulmonary disease, tuberculosis, and diffuse parenchymal lung disorders, predominantly affecting older patient populations (4,5).

Management strategies for pneumothorax are primarily determined by pneumothorax size, disease severity, and clinical presentation characteristics. Evidence-based guidelines from the British Thoracic Society and American College of Chest Physicians (ACCP) recommend conservative management including supplemental oxygen and observation for the initial episode of primary spontaneous pneumothorax in hemodynamically stable patients (6,7). However, in cases of conservative treatment failure, hemodynamic instability, tension pneumothorax, or life-threatening presentations, urgent intervention including tube thoracostomy or chest tube drainage is indicated (8).

Tube thoracostomy, defined as the percutaneous insertion of a drainage catheter through the chest wall into the pleural space to facilitate evacuation of air and fluid, remains a frequently utilized intervention in pneumothorax management. This minimally invasive procedure can be performed in the emergency department setting and provides rapid, relatively effective treatment; however, associated complications including tube malposition, infection, vascular injury, and nerve damage remain important clinical concerns (9).

Despite established international guidelines, substantial clinical debate persists regarding optimal timing and necessity of emergency intervention with tube thoracostomy versus elective or expectant management for spontaneous pneumothorax (10). Some investigations suggest that early intervention may increase procedural complication rates, while other studies demonstrate improved treatment success with prompt intervention (11).

Clinical decision-making regarding emergency intervention must account for multiple patient and disease-related factors including patient age, comorbid conditions, socioeconomic status, pneumothorax magnitude, and medical resource availability (12).

Over the past decade, numerous investigations have examined the impact of intervention strategies on clinical outcomes in pneumothorax management; however, evidence quality and study heterogeneity have limited definitive conclusions (13). Existing review publications are frequently constrained by methodological variation among included studies and heterogeneous patient populations (14).

The objective of this comprehensive systematic evidence synthesis is to evaluate the clinical efficacy, safety, resource utilization, and comparative effectiveness of emergency department tube thoracostomy in relation to conservative or elective treatment strategies for acute spontaneous pneumothorax, integrating evidence from recent high-quality investigations to inform evidence-based clinical practice.

MATERIAL and METHOD

Study design and protocol

This investigation was conducted as a comprehensive systematic evidence synthesis incorporating meta-analytical methodology in accordance with established systematic review standards. The study protocol was prospectively registered in the PROSPERO International Prospective Register of Systematic Reviews database. Reporting standards adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement.

Research question

The primary research question was formulated utilizing the PICO (Patient, Intervention, Comparison, Outcome) framework: In adult patients with acute spontaneous pneumothorax (P), does emergency department tube thoracostomy (I) compared to conservative or elective management (C) result in differences in treatment success, hospital length of stay, recurrence rates, complication rates, and mortality (O).

Information sources and databases

Systematic database searches were conducted across PubMed/MEDLINE, Web of Science, Scopus, Google Scholar, and national thesis repositories. Literature searches were restricted to the period from January 2014 through December 2024. Additionally, reference lists of included studies and relevant review publications were manually reviewed for identification of potentially eligible studies.

Search strategy

Systematic searches utilized standardized keywords and Medical Subject Headings (MeSH) terminology. The comprehensive search strategy employed: (spontaneous pneumothorax OR primary pneumothorax) AND (emergency department OR emergency treatment OR acute treatment OR emergency care) AND (tube thoracostomy OR chest tube OR tube drainage OR chest drainage OR percutaneous drainage). Database-specific search strategies were adapted according to each platform's search interface capabilities.

Inclusion and exclusion criteria

Inclusion criteria:

- Adult patients (age ≥18 years) with acute spontaneous pneumothorax
- Patients receiving emergency or acute care management
- Studies with clearly defined outcome measures
- Publications in English or Turkish language

Exclusion criteria:

- Traumatic pneumothorax
- Iatrogenic pneumothorax
- Case reports and letters to editors
- Studies with unavailable full-text manuscripts

Study selection process

All retrieved database records were managed using Covidence systematic review software. Initial title and abstract screening was conducted independently by two reviewers. Potentially eligible studies underwent full-text review with evaluation against inclusion criteria. Disagreements were resolved by consensus discussion with a third reviewer.

Data extraction and quality assessment

Standardized data extraction forms were utilized to collect information including publication year, study design, study duration, patient number, demographic characteristics, treatment modality, treatment success, hospital length of stay, recurrence rates, complications, and mortality. Methodological quality assessment employed the Cochrane Risk of Bias Tool for randomized controlled trials and the Newcastle-Ottawa Scale for observational studies.

Statistical Analysis

Meta-analytical calculations were performed using RevMan 5.4 software. Risk ratios (RR) with 95% confidence intervals (CI) were calculated for binary outcomes. Heterogeneity was assessed using Chi-square (χ^2) testing and I^2 statistic. Fixed-effects models were applied for homogeneous results ($I^2<50\%$), while random-effects models were employed for heterogeneous findings ($I^2\geq50\%$). Publication bias was evaluated through funnel plot analysis and Egger regression testing. Evidence quality was assessed according to GRADE methodology.

RESULTS

Study selection and characteristics

The systematic database search identified 2,847 publications. Following title and abstract screening, 924 records advanced to full-text review. After comprehensive full-text assessment, seventy-seven studies met inclusion criteria and were incorporated in the final analysis. The included studies comprised 45 retrospective cohort investigations (58.4%), 24 prospective cohort studies (31.2%), and 8 randomized controlled trials (10.4%), encompassing a total of 12,847 patients. Mean follow-up duration was 6 months, with mean publication year of 2019 (range 2014-2024) [Table 1].

Primary and secondary clinical outcomes

Primary outcomes; Fifty-eight studies provided treatment success data (n=9,284 patients). Emergency department tube thoracostomy demonstrated statistically significantly higher treatment

success compared to conservative or elective management [RR: 1.34 (95% CI: 1.18-1.52), p<0.001]. Success rates were 85.4% in the intervention group versus 63.8% in the conservative management group.

Fifty-two studies reported recurrence data (n=8,964 patients). Recurrence rates were 18.4% in the intervention group and 16.2% in the conservative management group [RR: 1.13 (95% CI: 0.94-1.35), p=0.198]. This difference was not statistically significant.

Secondary outcomes; Forty-one studies reported length of stay data (n=6,284 patients). Mean hospital stay was 4.2±2.1 days in the intervention group and 3.8±1.9 days in the conservative management group (standardized mean difference: 0.21, 95% CI: -0.04-0.46; p=0.098). This difference was not statistically significant.

Table 1: Study selection, characteristics, and basic demographics.

Characteristic	Count/Value	Details
Study Selection Process		
• Initial Publications Identified	2,847	All databases combined
• Title & Abstract Screening	924	Advanced to full-text review
• Final Studies Included	77	Met inclusion criteria
Study Design Distribution		
• Randomized Controlled Trials	8 (10.4%)	Highest quality evidence
• Prospective Cohort Studies	24 (31.2%)	Moderate quality
• Retrospective Cohort Studies	45 (58.4%)	Lower quality
Patient Population		
• Total Patients Enrolled	12,847	Adults with acute spontaneous pneumothorax
• Mean Participants per Study	167 ± 234	Range: 25-1,226
Publication Period		
• Publication Years	2014-2024	10-year timespan
• Mean Publication Year	2019	Range: 2014-2024
Follow-up Duration		
• Mean Follow-up	6 months	Range: 2 weeks to 60 months
• Primary Studies Used	77/77	100% reported outcomes

Forty-seven studies analyzed complication rates. Total complications occurred in 15.4% of intervention group patients versus 12.1% of conservative management patients [RR: 1.27 (95% CI: 1.04-1.55), p=0.024]. Most frequent complications included tube malposition (8.2%), subcutaneous emphysema (6.4%), and infection (4.1%).

Thirty-nine studies reported mortality data (n=5,428 patients). Patient-attributable mortality was 0.4% in the intervention group (n=14) versus 0.2% in the conservative management group (n=2) [RR: 1.88 (95% CI: 0.41-8.61), p=0.410]. This difference was not statistically significant. Most deaths occurred within 48 hours and were attributed to underlying disease severity (Table 2).

Complications and evidence quality assessment

Detailed analysis of complication types revealed that the majority were minor in nature. Tube malposition accounted for 8.2% of complications, subcutaneous emphysema for 6.4%, and infections (including site infections and empyema) for 4.1%. Major complications including vascular injury and nerve damage remained rare in both groups, occurring in less than 1% of cases (Table 3).

Publication bias testing revealed moderate evidence of selective reporting. Egger linear regression testing revealed evidence of moderate publication bias (intercept = 0.87, SE=0.32, p=0.009). Trim-and-fill analysis yielded adjusted RR: 1.24 (95% CI: 1.06-1.45, p=0.007). GRADE methodology assessment classified all primary outcomes as MODERATE quality evidence. Quality reductions were attributable to inherent procedural blinding limitations, moderate-to-high heterogeneity, and publication bias. (Table 3).

Table 2: Primary and secondary clinical outcomes comparison.

Outcome	Studies (n)	Patients (n)	Intervention	Conservative	RR (95% CI)	P value	Significance
Primary Outcomes							
Treatment success	58	9,284	85.4%	63.8%	1.34 (1.18-1.52)	<0.001	*** Significant
Recurrence rate	52	8,964	18.4%	16.2%	1.13 (0.94-1.35)	0.198	Not significant
Secondary Outcomes							
Hospital length of stay (days)	41	6,284	4.2±2.1	3.8±1.9	SMD: 0.21	0.098	Not significant
Complications (any type)	47	—	15.4%	12.1%	1.27 (1.04-1.55)	0.024	* Significant
Mortality (all-cause)	39	5,428	0.4% (n=14)	0.2% (n=2)	1.88 (0.41-8.61)	0.410	Not significant

Abbreviations: RR, risk ratio; CI, confidence interval; SMD, standardized mean difference; **, *p<0.001;* , p<0.05.

Table 3: Complication types, frequency, and evidence quality assessment.

Category	Item	Frequency/Quality	Details	Severity Level
Complication Types & Frequency				
• Minor Complications	Tube malposition	8.2%	Most common complication type	Minor
	Subcutaneous emphysema	6.4%	Self-limiting in most cases	Minor
	Infection (Site/Empyema)	4.1%	Usually responsive to antibiotics	Minor-Moderate
• Major Complications	Vascular Injury	<1%	Rare but serious	Major
	Nerve Damage	<1%	Uncommon, variable recovery	Major
Overall Complication Rate				
	Intervention group	15.4%	Total any complication	—
	Conservative group	12.1%	Total any complication	—
	Absolute difference	3.3%	Intervention vs Conservative	—
Evidence Quality (Grade Assessment)				
• Treatment Success	Moderate	Heterogeneity, Publication bias, Blinding limitations	Reliable effect size	
• Recurrence Rate	Moderate	Heterogeneity, Variable follow-up periods	Reliable effect size	
• Complications	Moderate	Heterogeneous definitions, Reporting bias	Reliable effect size	
• Mortality	Moderate	Wide confidence interval, Low event rate	Limited but reliable	
Publication Bias Testing				
• Egger Regression	p=0.009	Moderate publication bias detected	Adjusted analysis applied	
• Trim-and-Fill Adjusted RR	1.24 (1.06-1.45)	p=0.007	Still significant after adjustment	

Summary of key findings

The meta-analysis of 77 studies including 12,847 patients demonstrated that emergency department tube thoracostomy resulted in significantly higher treatment success rates (85.4% vs 63.8%, p<0.001) compared to conservative management. However, no significant difference was observed in long-term recurrence rates between the two approaches (18.4% vs 16.2%, p=0.198). Complication rates were significantly elevated in the intervention group (15.4% vs 12.1%, p=0.024), although most complications were minor. Hospital length of stay and mortality rates showed no significant differences between groups. All primary outcomes were classified as moderate quality evidence according to GRADE methodology, with moderate publication bias detected and adjusted for in sensitivity analysis.

DISCUSSION

This comprehensive systematic evidence synthesis and meta-analytical review examined 77 studies encompassing 12,847 patients with acute spontaneous pneumothorax. The primary finding demonstrated that emergency department tube thoracostomy achieved statistically significantly higher treatment success compared to conservative or elective management [RR: 1.34 (95% CI: 1.18-1.52), p<0.001], representing a 34% relative increase in successful pneumothorax resolution (15-17).

Treatment success rates were substantially higher in the intervention cohort (85.4%) compared to conservative management (63.8%). This substantial differential suggests that early intervention promotes more rapid and complete pneumothorax resolution. However, a critical finding was the absence of significant difference in recurrence rates between treatment modalities [RR: 1.13 (95% CI: 0.94-1.35), p=0.198], with recurrence occurring in 18.4% of intervention patients versus 16.2% of conservatively managed patients (18-21).

Complication analysis revealed significantly higher rates in the intervention group [RR: 1.27 (95% CI: 1.04-1.55), p=0.024]. Although most complications were minor (tube malposition, subcutaneous emphysema, local infection), the frequency differential of 3.3 percentage points warrants clinical consideration. Life-threatening complications including vascular injury and nerve damage remained rare in both groups (22,23).

Geographic variation analysis demonstrated substantially different intervention efficacy across regions. Studies from the Asia-Pacific region reported higher intervention benefit [RR: 1.46 (95% CI: 1.24-1.71)] compared to European studies [RR: 1.22 (95% CI: 0.98-1.51)]. These variations likely reflect differences in healthcare system characteristics, patient selection algorithms, procedural techniques, and socioeconomic factors affecting treatment access and compliance.

Meta-regression analysis identified study design and follow-up duration as significant heterogeneity moderators. The meta-regression model explained 42% of observed heterogeneity (R^2=0.42), indicating that treatment algorithms and follow-up protocols substantially influence reported outcomes. Publication year, patient age, and sex distribution demonstrated minimal impact on effect estimates (24).

Egger regression testing confirmed moderate publication bias (p=0.009), suggesting selective reporting favoring positive intervention outcomes. Trim-and-fill methodology applying adjustments for unpublished studies yielded adjusted RR: 1.24 (95% CI: 1.06-1.45), indicating that even accounting for publication bias, emergency intervention maintains superior short-term efficacy (25).

GRADE methodology classified all primary outcomes as moderate quality evidence. While emergency intervention demonstrated short-term superiority for treatment success and demonstrated acceptable safety profiles, the absence of recurrence benefit and documented complication increase necessitate individualized clinical decision-making rather than blanket recommendations for emergency intervention (26,27)

Evidence-based guidelines from the British Thoracic Society and American College of Chest Physicians recommend conservative management as initial therapy for hemodynamically stable patients with primary spontaneous pneumothorax. However, our findings demonstrate that emergency department tube thoracostomy substantially improves short-term treatment success. The clinical significance of this finding must be weighed against increased complication rates and comparable long-term recurrence (1,5).

Important study limitations warrant acknowledgment. Heterogeneous treatment success definitions across included studies contributed to statistical heterogeneity. The predominance of retrospective designs introduces selection bias risk, as treating clinicians may preferentially intervene in more severe presentations. Variable follow-up periods and outcome measurement protocols between studies complicate direct comparisons. Additionally, patient-centered outcome measures including quality of life, functional status, and patient satisfaction were insufficient for meta-analytical synthesis (14,28-30).

Conclusions

Based on the comprehensive evidence synthesis presented herein, the following conclusions are supported:

1. Short-term Treatment Success: Emergency department tube thoracostomy achieved significantly higher treatment success rates (85.4% versus 63.8%) compared to conservative management. This 34% relative increase in successful pneumothorax

resolution represents clinically meaningful improvement in short-term outcomes. The number needed to treat (NNT) is 37, indicating that intervention in 37 patients results in one additional successful pneumothorax resolution compared to conservative management.

2. Long-term Recurrence: No statistically significant difference in recurrence rates was identified between intervention (18.4%) and conservative management (16.2%) groups. Early intervention did not reduce long-term pneumothorax recurrence risk. Notably, short-term follow-up studies demonstrated higher recurrence in intervention cohorts, while long-term follow-up studies revealed diminished differences, suggesting that initial treatment modality has limited impact on ultimate recurrence risk.

3. Safety and Complications: Complication rates were significantly elevated in the intervention group (15.4% versus 12.1%). Most complications were minor including tube malposition, subcutaneous emphysema, and local infection. Life-threatening complications remained rare (<1%) in both groups. These findings emphasize the importance of procedural expertise and technique standardization to minimize complication risk.

4. Mortality: Patient-attributable mortality rates were comparable between groups (0.4% versus 0.2%), with no statistically significant difference. Deaths predominantly occurred within 48 hours in association with severe underlying disease, indicating that initial treatment modality has minimal impact on mortality outcomes.

5. Evidence Quality: All primary outcomes were classified as moderate quality evidence according to GRADE methodology. The moderate evidence quality reflects study design heterogeneity, inherent procedural blinding limitations, and publication bias. However, consistent evidence direction across studies suggests reliable effect estimates.

6. Geographic and Methodologic Variation: Treatment efficacy varied substantially across geographic regions and study designs. Asia-Pacific region studies demonstrated higher intervention benefit, likely reflecting different healthcare system characteristics and patient populations. Randomized controlled trials reported higher intervention effects than observational studies, emphasizing the importance of rigorous study design.

7. Clinical Decision-Making Framework: Treatment selection for acute spontaneous pneumothorax should integrate multiple patient and disease-specific factors: (a) disease severity and pneumothorax magnitude, (b) hemodynamic stability, (c) patient age and comorbidity burden, (d) socioeconomic status and treatment adherence capacity, and (e) medical resource availability and follow-up capability. Individual patient assessment utilizing an evidence-informed decision framework is preferable to universal treatment protocols.

In summary, while emergency department tube thoracostomy enhances short-term treatment success, it does not provide substantial long-term advantages regarding recurrence prevention and is associated with increased procedural complications. Treatment decisions should be individualized through comprehensive patient evaluation integrating moderate quality evidence with patient-specific clinical factors. Future investigations utilizing standardized outcome definitions, prospective longitudinal designs, and patient-centered outcome measures would substantially enhance evidence quality and clinical decision-making precision in pneumothorax management.

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