Effectiveness and outcomes of 2 therapeutic interventions for cardiac tamponade
A retrospective observational study

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Abstract
Pericardial effusions can either be drained by percutaneous pericardiocentesis (PCC) or by surgical pericardiotomy (SP), with limited evidence of superiority for the management of cardiac tamponade (CTa).

This study uses the US Nationwide Emergency Department Sample database to investigate the effectiveness of SP and PCC in patients with CTa in terms of clinical outcomes and healthcare costs.

Retrospective observational study conducted on the US Nationwide Emergency Department Sample 2014 dataset CTa patients. Descriptive and multivariate logistic regression analyses were done to assess the impact of different procedures (none, SP, PCC, SP, and PCC) on mortality.

A total of 10,410 CTa patients were included, of which 28.9% underwent no procedure, 32.9% underwent SP, 30.2% underwent PCC and 8.0% underwent SP and PCC. Mortality rates were highest in patients undergoing no procedure (22.3%) followed by PCC (15.0%), SP and PCC (11.5%), and then SP (9.6%) (P<.001). SP patients had longer length of stay (11.65 vs 8.16 days, P<.001) and higher total charges ($162,889.1 vs $100,802, P<.001) compared to PCC patients. Undergoing any procedure for CTa reduced the rate of mortality compared to no procedure with SP being the most effective (OR=0.387, 95% CI 0.239–0.626), followed by SP & PCC (OR=0.387, 95% CI 0.239–0.626), and then PCC (OR=0.582, 95% CI 0.446–0.760).

Adult CTa patients treated with SP had lower mortality rates but longer length of stay and higher healthcare expenses. This SP associated benefit remained consistent across different subpopulations after stratifying by age and potential disease etiology.

Abbreviations: CTa = cardiac tamponade, NEDS = nationwide emergency department sample, PCC = percutaneous pericardiocentesis, SP = surgical pericardiotomy.

Keywords: cardiac tamponade, healthcare expenses, mortality, percutaneous pericardiocentesis, pericardial effusion, surgical pericardiectomy.

1. Introduction
The heart is surrounded by a pericardial cavity which contains up to 50 mL of plasma ultrafiltration product.[1,2] Many pathological processes can infect, inflame or injure the pericardium and result in a pericardial effusion.[2] If the fluid accumulates rapidly or extensively in the pericardium, it can compress on the heart and impair cardiac filling, and lead to cardiac tamponade (CTa) and its potentially life-threatening hemodynamic changes.[2]

Pericardial effusions can either be drained by percutaneous pericardiocentesis (PCC) or by surgical pericardiotomy (SP).[3,4] As the most optimal procedure remains controversial,[3–5] the European Society of Cardiology still recommends both procedures.[10] Whereas PCC is less invasive, faster and done at the patient’s bedside in the emergency room via percutaneous needle insertion, SP is done in the operating room and involves opening of the pericardium. In patients with CTa, studies comparing immediate results and long-term outcomes of patients who underwent PCC versus SP showed no significant difference in mortality and complications between both techniques.[1,11] Nevertheless, PCC was associated with incomplete fluid evacuation and more recurrence than SP.[9,11–13] In patients with malignant effusions, the current literature contains contradictory results regarding the preferred management technique. On one hand, SP was reported to be superior to PCC in preventing recurrence, providing symptom relief, and decreasing morbidity.[14–17] On the other hand, PCC was associated with fewer complications compared to SP.[18]

To date, limited evidence exists on the most optimal technique for the management of pericardial effusions. This study uses a US Emergency Department (ED) database to investigate the
effectiveness of SP and PCC in adult patients with CTa. It compares SP and PCC in terms of clinical outcomes (mortality and length of stay) and healthcare costs.

2. Materials and methods

2.1. Study design and setting

This is a retrospective observational study of adult CTa patients in the Nationwide Emergency Department Sample (NEDS) 2014 public release dataset. In the US, NEDS is the largest all-payer ED database publically available through the Agency for Healthcare Research and Quality as part of the Healthcare Cost and Utilization Project. [dataset] The dataset contains medical and non-clinical data on 137,807,901 ED visits, weighted for national estimates, at 945 hospital-owned EDs consisting of a non-clinical sample of hospital-based EDs across 33 participating US states and District of Columbia. [dataset] Hospitals are sampled according to census region, trauma center designation, location, ownership and teaching status for those sampled hospitals to be representative of hospitals throughout the US. The above stratification variables are used to statistically weigh the stratified sample of patients in order to examine national estimates.

The Institutional Review Board (IRB) at the American University of Beirut approved the use of this de-identified dataset for this study. HCUP Data Use Agreement (DUA) training course was completed and Nationwide Data Use Agreement signed by research participants. As per HCUP requirements to respect patient's rights and privacy, data variables for a sample of 10 or less participants was excluded.

2.2. Study population

A total of 12,036 potentially eligible weighted adult ED visits with CTa were initially screened and 1,666 were excluded because of age less than 18 years, pregnancy complications, childbirth, puerperium, trauma or congenital anomalies. As such, a total of 10,410 weighted adult ED visits with CTa were included in our study. No procedure was done on 3011 (28.9%) patients, 3425 (32.9%) underwent SP, 3140 (30.2%) had PCC and 834 (8.0%) underwent both procedures (Fig. 1). A slightly higher proportion of CTa patients consisted of males (52.6%) with mean age of 62 years (95% CI 61.52–62.64), residing in large central (31.5%) and large fringe (25.0%) metropolitan areas. Most of the study population was covered by Medicare (51.4%), private insurances (28.4%) or Medicaid (14.9%). They presented mostly to South (36%) and Midwest (25.4%) hospitals. Patients had associated endocrine, nutritional, metabolic or immunity disorders (80.3%), respiratory system diseases (71.6%), diseases of blood or blood-forming organs (54.3%), digestive system diseases (40.8%), neoplasms (30.7%) and infectious or parasitic diseases (25.2%). Overall mortality rate during hospital stay was 15.0% (Table 1).

When divided into 4 groups according to the treatment done, patients undergoing no procedure were of slightly higher age (63.36 years, 95% CI 62.50–64.61) when compared to those undergoing both procedures (59.5 years, 95% CI 57.62–61.42), SP (59.6 years, 95% CI 57.62–61.42) and PCC (61.7 years, 95% CI of 60.76–62.71 and 60.67–62.75, respectively) (P-value of .002).

Only chronic condition indicators that were significantly different between groups were presented in Table 2. Patients who underwent SP had more endocrine, nutritional, metabolic and immunity disorders (83.3 vs 78.7%, P = .026), respiratory system diseases (77.0 vs 68.8%, P < .001), blood and blood-forming organs diseases (57.9% vs 49.9%, P = .003), digestive system diseases (42.8 vs 41.0%, P < .001) and neoplasms (34.8 vs 30.3%, P < .001).

3. Results

3.1. Characteristics of CTa patients

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3.2. Procedural and hospitalization outcomes

Mortality rates were significantly different between groups, with patients undergoing no procedure having the highest rates (22.3%) followed by those who underwent PCC (15.0%), both procedures (11.5%) then SP (9.6%) (P < .001).

Moreover, disposition of CTa patients significantly differed among groups. A higher proportion of patients undergoing no procedure were transferred to short-term hospitals or other
4. Discussion

CTa is a rapidly fatal medical emergency and the associated mortality risk depends on the speed of recognition and management of the condition, the treatment provided and the underlying cause. Mortality rates range from 13.3% in patients without malignancy to 76.5% for malignant effusions. This observational study of over 10,000 CTa patients is the largest to date to evaluate different management techniques for CTa in terms of procedural and hospitalization outcomes. In this study, the overall mortality rate of CTa patients was 15.0%.

SP was found to be superior to SP & PCC, which was superior to PCC alone in CTa patients. Overall mortality rates ranged from 9.6% (95% CI 8.0–11.6) in SP patients to 22.3% (95% CI 19.5–25.3) in patients undergoing no procedure. These observations are in line with those of a previous study by Petcu et al on the efficiency of SP vs PCC in 192 pericardial effusions associated with CTa where the in-hospital mortality rate was 15.1%. SP and PCC patients included in our study had lower mortality rates, which could be related to different patients characteristics prior to adjusting for confounders including the presence of neoplasm. Indeed, post procedure survival is significantly influenced by the presence of a malignant etiology of the effusion. Other studies, however, did not report variation in mortality rates according to procedure type. Horr et al examined 1281 patients requiring drainage of pericardial effusions without observed difference in mortality rates by procedure.[13] Reported mortality rates were also much lower than in our study where only 4.9% of patients who underwent PCC died compared to 6.1% of those who underwent surgical drainage. In previous observational studies, there were, however, unavoidable differences in patient profiles, effusion etiologies and hemodynamic stability in both treatment groups, and CTa was confirmed in only 71% of patients who underwent PCC and in 54% of those who underwent SP.[3]

In our observational study, despite the established perioperative risks of undergoing SP for CTa, SP was shown to offer a survival advantage compared to PCC. This significant mortality difference between both procedures cannot be merely explained by intra-procedural mortality, as per prior studies. The procedural complication rates related to SP have been reported to be up to 4% with sub-xiphoid drainage[8,23,24] and 12% with thorascopic windows.[25] On the other hand, major complications occurred in only 1 to 1.6% of PCC cases.[4] SP is an operative approach that offers definitive management but normally requires general anesthesia and intubation, both of which can have detrimental effects on CTa patients.[3] When compared to PCC patients, SP patients are more likely to suffer from hemodynamic instability within 48 hours of the procedure, yet they are less likely to have recurrence.[3,19,26] Nonetheless, isolated PCC provides instantaneous symptomatic relief at lower cost at the expense of not achieving complete fluid evacuation.[14] Given that clinical CTa is associated with effusion re-accumulation,[3] the higher mortality rates among patients who underwent PCC alone or both procedures might be attributed to higher re-accumulation rates after PCC though this was not directly measured in our study. According to a study by Gumrukcuoglu et al., no difference was noted in complication rates between PCC and SP and PCC; however, SP patients were less likely to develop complications compared to both PCC and SP and PCC groups.[27] It is also possible that patients who underwent
Table 1
Characteristics and hospitalization outcomes of cardiac tamponade patients.

| Continuous Variables | Mean (95% CI) | Median | IQR (Q3–Q1) |
|----------------------|---------------|--------|-------------|
| Age (yr)             | 62.08 (61.52–62.64) | 63     | 74–52       |

| Categorical Variables | Frequency (N=10410) | Percentage (95% CI) |
|-----------------------|----------------------|---------------------|
| Gender                |                      |                     |
| Male                  | 5480                 | 52.6 (50.8–54.5)    |
| Female                | 4930                 | 47.4 (45.5–49.2)    |
| Patient location: NCHS urban-rural code |                   |                     |
| Large central metropolitan | 3255             | 31.5 (30.3–32.8)    |
| Large fringe metropolitan  | 2578            | 25.0 (23.8–26.3)    |
| Medium metropolitan    | 2312                | 22.4 (21.3–23.5)    |
| Small metropolitan     | 929                 | 9.0 (8.1–10.0)      |
| Micropolitan           | 781                 | 7.6 (6.8–8.4)       |
| Not metropolitan or micropolitan | 462          | 4.5 (3.8–5.3)       |
| Expected primary payer |                     |                     |
| Medicare              | 5344                | 51.4 (49.5–53.2)    |
| Medicaid              | 1550                | 14.9 (13.7–16.2)    |
| Private including HMO | 2966                | 28.4 (26.8–30.1)    |
| Self-pay              | 292                 | 2.8 (2.3–3.6)       |
| No charge             | 16                  | 0.2 (0.1–0.4)       |
| Other                 | 243                 | 2.3 (1.8–2.9)       |
| Hospital Region       |                      |                     |
| Northeast             | 1986                | 19.1                |
| Midwest               | 2646                | 25.4                |
| South                 | 3751                | 36                  |
| West                  | 2028                | 19.5                |
| Chronic condition indicator |                |                     |
| Infectious and parasitic disease | 2618            | 25.2 (23.6–26.8)    |
| Endocrine, nutritional, metabolic and immunity disorders | 3199              | 30.7 (29.0–32.5)    |
| Blood and blood-forming organs diseases | 8364           | 80.3 (78.8–81.8)    |
| Mental disorders      | 3567                | 34.3 (32.5–36.0)    |
| Diseases of the nervous system | 3363          | 32.3 (30.6–34.1)    |
| Diseases of the circulatory system | 10410      | 100                 |
| Diseases of the respiratory system | 7456            | 71.6 (69.9–73.3)    |
| Diseases of the digestive system | 4248          | 40.8 (39.0–42.6)    |
| Diseases of the genitourinary system | 5374        | 51.6 (49.8–53.5)    |
| Diseases of the skin and subcutaneous tissue | 818            | 7.9 (6.9–8.9)       |
| Diseases of the musculoskeletal system | 2453          | 23.6 (22.0–25.2)    |
| Symptoms, signs, and ill-defined conditions | 6173          | 59.3 (57.5–61.1)    |
| Injury and poisoning  | 3130                | 30.1 (28.4–31.8)    |
| Factors influencing health status and contact with health services | 7032          | 76.2 (74.6–77.7)    |
| Disposition of patient from ED |                |                     |
| Home                  | 187                 | 1.8 (1.4–2.4)       |
| Transfer to short-term hospital & other facilities | 270           | 2.6 (2.1–3.2)       |
| Admitted              | 9777                | 93.9 (93.0–94.7)    |
| Death                 | 146                 | 1.4 (1.0–1.9)       |
| Other (Against medical advice & unknown destination) | 30            | 0.3 (0.1–0.5)       |
| Patient Disposition   |                      |                     |
| Routine & Home health care & Discharge alive, destination unknown | 5533        | 56.6 (54.7–58.5)    |
| Transfer to short-term hospital & other facilities | 2768          | 28.3 (26.6–30.1)    |
| Against medical advice | 55              | 0.6 (0.3–0.9)       |
| Died in hospital      | 1418                | 14.5 (13.2–15.9)    |
| Died visit            |                      |                     |
| Did not die           | 8833                | 85.0 (83.6–86.2)    |
| Died in ED/hospital   | 1564                | 15.0 (13.9–16.4)    |

Continuous Variables | Mean (95% CI) | Median | IQR (Q3–Q1) |
|---------------------|---------------|--------|-------------|
| Total ED charges ($)| 3066.35 (2876.78–3255.91) | 2093 | 3276–1494.5 |
| Total ED and inpatient charges ($) | 155687.95 (145750.84–165625.06) | 87611 | 167935–44455 |
| Length of stay      | 10.41 (9.90–10.93) | 7      | 13–4        |

CI = confidence interval, ED = emergency department, HMO = health maintenance organization, IQR = interquartile range, NCHS = National Center for Health Statistics, Q1 = first quartile, Q3 = third quartile.
## Table 2  
Characteristics and hospitalization outcomes of cardiac tamponade patients after stratification by procedure.

| Continuous variables | No procedure (N=3011) | SP (N=3425) | PCC (N=3140) | SP & PCC (N=834) | P-value |
|----------------------|-----------------------|-------------|--------------|------------------|---------|
| Age (yr)             | 63.56 (62.50–64.61)   | 61.74 (60.76–62.71) | 61.71 (60.67–62.75) | 59.52 (57.62–61.42) | .002    |
| Categorical Variables |                       |             |              |                  |         |
| Gender               |                       |             |              |                  |         |
| Male                 | 1611                  | 1666        | 1747         | 3103             | .459    |
| Female               | 1400                  | 1608        | 1474         | 368              | 4.41    |
| Patient location: NCHS urban-rural code |             |             |              |                  |         |
| Large central metropolitan | 807                | 1037        | 294          | <.001            |
| Large fringe metropolitan | 712                 | 955         | 262          | 207              | <.001    |
| Medium metropolitan | 673                   | 738         | 295          | 9.7              |
| Small metropolitan | 338                   | 238         | 78           | 3.8              |
| Micropolitan | 276                   | 257         | 64           | 2.7              |
| Not metropolitan or micropolitan | 175              | 104         | 35           | 2.2              |
| Expected primary payer |                       |             |              |                  |         |
| Medicare            | 1695                  | 1531        | 344          | 0.001            |
| Medicaid            | 473                   | 472         | 149          | 0.13             |
| Private including HMO | 602                 | 989         | 315          | 29.2             |
| Self-pay            | 85                    | 83          | 46           | 5.5              |
| Other & No charge   | 66                    | 64          | 2.1          | 4.7              |
| Hospital Region     |                       |             |              |                  |         |
| Northeast           | 565                   | 582         | 18.6         | <.001            |
| Midwest             | 826                   | 856         | 212          | 20.7             |
| South               | 1057                  | 971         | 310          | 31.4             |
| West                | 563                   | 730         | 33.6         | 19.3             |
| Chronic condition indicator | 2950            | 3103        | 823          | 0.03             |
| Neoplasms           | 684                   | 952         | 470          | 0.3              |
| Endocrine, nutritional, metabolic and immunity disorders | 2354 | 2472 | 684 | 0.26 |
| Blood and blood-forming organs diseases | 1612 | 1567 | 405 | 0.003 |
| Diseases of the respiratory system | 2001 | 2162 | 658 | 0.001 |
| Diseases of the digestive system | 1035 | 1286 | 461 | 0.06 |
| Symptoms, signs and ill-defined conditions | 1919 | 1860 | 474 | 0.01 |
| Injury and poisoning | 1005                | 856         | 19.3         | 0.03             |
| Factors influencing health status and contact with health services | 2165 | 2410 | 683 | 0.03 |
| Disposition of patient from hospital |             |             |              |                  |         |
| Routine and Home health care and Discharge alive, destination unknown & AMA | 849 | 1983 | 562 | 0.001 |
| Transfer to short-term hospital and other facilities | 1047 | 651 | 176 | 0.03 |
| Died in hospital | 599                   | 402         | 132          | 11.5             |
| Died did not die    | 2337                  | 738         | 88.5         | 0.001            |
| Died in ED/hospital | 669                   | 469         | 11.5         | 9.7               |
| Categorical variables | Mean (95% CI) | Mean (95% CI) | Mean (95% CI) | P-value |
| Total ED charges ($) | 2610.49 (2434.52–2786.46) | 3201.86 (2698.36–3705.36) | 2307.89 (2032.51–2583.28) | <.001 |
| Total ED and inpatient charges ($) | 162889.14 (149380.66–176397.63) | 100820.53 (92911.56–108693.50) | 136232.98 (121923.74–150542.24) | <.001 |
| Length of stay | 11.65 (10.89–12.42) | 8.16 (7.66–8.67) | 11.19 (10.08–12.29) | <.001 |

AMA = against medical advice, CI = confidence interval, ED = emergency department, F = frequency, HMO = health maintenance organization, NCHS = National Center for Health Statistics, PCC = percutaneous pericardioentesis, SP = surgical pericardiectomy.
PCC were poor surgical candidates with poorer prognosis to start with. In fact, 30.3% of PCC patients included in our study were oncology patients with malignant effusions, who tend to suffer from cachexia and multiple comorbidities. Additionally, PCC is possibly preferred for terminal patients since it is less painful and ensures faster recovery, although not adequate as definitive management.

Moreover, in our study, both length of stay and total charges were significantly higher in CTa patients treated with SP as compared to PCC. Saltzman et al previously reported a significant difference of 9 days between SP and PCC. Also, Zack et al reported significantly longer hospital stay and higher total charges for SP.

According to the European Society of Cardiology, urgent SP rather than PCC is the treatment of choice for CTa in the event of hemopericardium associated with severe chest trauma, aortic dissection or ventricular free wall rupture in acute myocardial infarction as well as for purulent effusions in septic patients and loculated or posterior effusions that are not accessible percutaneously. PCC also has relative contraindications namely severe thrombocytopenia, uncorrected coagulopathy and anticoagulant therapy. This heterogeneity between SP and PCC patients in etiology and location of the effusion causing CTa is not easily accounted for and usually renders comparison between surgical and nonsurgical management rather difficult. Additionally, in our study, patients with specific chronic diseases had significant differences in how they were managed in that those patients were treated with SP more often than with PCC. This shows that SP might be a better approach for chronic patients for long-term palliation. Sixty percent of pericardial effusions are associated with a known medical condition, the treatment of which would be that of the underlying disease.

The choice of treatment should thus be individualized while taking into consideration the underlying etiology and the patient’s prognosis, risks and success rates of SP and PCC, the institutional setting and local expertise available. In order to minimize risk and mortality associated with PCC, patients should be selected according to the underlying disease process, location and volume of the effusion as well as patient’s coagulation status. Limitations of this study lie in its retrospective design and are related to unavailability of potentially confounding clinical variables including clinical severity scale, New York Heart Association class, criteria adopted for CTa diagnosis, vital signs such as heart rate and blood pressure, etiology of effusion, platelets number at the time of procedure, SP technique and mortality cause. Moreover, the NEDS database does not contain any data related to the patients’ CTa characteristics, the medical management of patients who received no intervention or the criteria adopted for a patient to undergo both procedures. Available confounders including chronic medical condition indicators such as neoplasms that contribute to clinical severity were however adjusted for, and since all patients had CTa, it would be safe to assume that they had all comparable clinical severity. Lack of data on recurrence and follow up among transferred patients are other limitations that might have underestimated mortality rates in different groups. However, there is no reason to suspect that it affected a specific group more than another. Despite limitations, study findings reflective of outcomes across a large sample of US hospitals are expected to be consistent in other similar settings.

### Table 3

| Procedure | OR (95% CI) | P-value | OR (95% CI) | P-value |
|-----------|-------------|---------|-------------|---------|
| **Unadjusted** | | | | |
| SP | 0.371 (0.284–0.485) | <.001 | 0.323 (0.244–0.429) | <.001 |
| PCC | 0.614 (0.478–0.790) | <.001 | 0.582 (0.446–0.769) | <.001 |
| SP and PCC | 0.456 (0.289–0.718) | <.001 | 0.387 (0.239–0.628) | <.001 |
| **Adjusted** | | | | |

| | | | |
| **OR** | **(95% CI)** | **P-value** | **OR** | **P-value** |
| | | | | |
| | | | | |

### Table 4

| Procedure (No) | ≤ 65 yr | ≥ 66 yr | No | Neoplasms |
|----------------|---------|---------|----|-----------|
| | OR (95% CI) | P-value | OR (95% CI) | P-value |
| | | | | |
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| | | | | |

**CI = confidence interval, OR = odds ratio, PCC = percutaneous pericardiocentesis, SP = surgical pericardiocentesis.**

1. Adjusted for age, patient location, primary expected payer, region of hospital and statistically significant variables of chronic condition indicators namely neoplasms, endocrine, nutritional and metabolic diseases and immunity disorders, diseases of the respiratory system, diseases of the digestive system, symptoms, signs and ill-defined conditions, injury and poisoning and factors influencing health status and contact with health services.

2. Adjusted for age, patient location, primary expected payer, region of hospital and statistically significant variables of chronic condition indicators namely neoplasms, endocrine, nutritional and metabolic diseases and immunity disorders, diseases of the respiratory system, diseases of the digestive system, symptoms, signs and ill-defined conditions, injury and poisoning and factors influencing health status and contact with health services.
5. Conclusions

Adult CTA patients treated with SP had lower mortality rates but longer hospital stay and higher healthcare expenses. This SP associated benefit remained consistent across different subpopulations after stratifying by age and potential disease etiology. As each of the discussed interventions has benefits and risks, no single treatment plan can be universally and blindly adopted. Further areas of research should provide a detailed and structured mortality analysis that takes into account the effusion etiology, cause of death, clinical status and clinical risks of patients.

Author contributions

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