Pericardiocentesis in trauma: A systematic review

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BACKGROUND: Pericardiocentesis (PCC) had been taught as a mandatory skill in the Advanced Trauma Life Support (ATLS®) course as a bridge to definitive surgical therapy for traumatic pericardial tamponade since its inception in 1978. Immediate thoracotomy for penetrating trauma to the heart and chest has resulted in the decreased use of PCC in trauma. PCC is now offered as an optional skill in the ninth edition of the ATLS®. A review of the literature regarding the use and effectiveness of PCC in traumatic pericardial tamponade in the modern era is necessary to better define its current role in trauma care.

METHODS: Scientific publications from 1970 to 2010 involving PCC after trauma were identified. The Preferred Reporting Items for Systematic reviews and Meta-Analyses was used. Human studies describing acute traumatic tamponade were included. Publications involving nontraumatic or chronic pericardial tamponade from effusions caused by inflammatory, infectious, or neoplastic etiology were excluded. Publications were categorized by level of evidence.

RESULTS: Of the 135 publications identified, 27 were included, composing of 2,094 trauma patients with suspected cardiac tamponade. The reported use of PCC decreased from 45.9% of patients in the period 1970 to 1979 down to 6.4% of patients in the period between 2000 and 2010 ($p < 0.05$). Reported rates describing the use of PCC as the sole intervention decreased from 13.7% in the period 1970 to 1979 to 2.1% in the period 2000 to 2010 ($p < 0.05$). Survival analysis after PCC was possible for 380 patients. Overall survival following PCC was 83.4% (n = 317) and 91.8% (n = 145) when used as the sole intervention. In patients who received PCC then thoracotomy, survival rate was 79.5% (n = 178).

CONCLUSION: Studies on the use of PCC for trauma are limited and biased toward survivors. The reported survival rate is high. There remains a limited role for PCC in nontrauma centers where definitive surgical management is not immediately available and transport time to a higher level of care facility supports the use of temporary decompression by PCC. (*J Trauma Acute Care Surg*. 2013;75: 543–549. Copyright © 2013 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Systematic review, level III.

KEY WORDS: Pericardiocentesis; traumatic cardiac tamponade; systematic review.

Pericardiocentesis had previously been taught in the advanced trauma life support (ATLS®) course as a bridge to definitive surgical therapy when facing traumatic pericardial tamponade since the course was introduced in 1978.[1] Initially viewed as a diagnostic and potentially therapeutic procedure, the advent of Focused Assessment Sonography in Trauma (FAST) has largely replaced the use of pericardiocentesis for diagnosis of tamponade owing to its high accuracy in detecting the presence of pericardial fluid by an experienced operator.[2–4]

Literature describing faster definitive treatment and improved outcomes using immediate thoracotomy for penetrating trauma to the heart and chest[5–11] resulted in a reduction in the use of pericardiocentesis as a primary treatment of traumatic pericardial tamponade. The role of pericardiocentesis is described as a temporizing maneuver when thoracotomy is not an available option. In its ninth and most recent edition, the ATLS® course emphasizes the role of immediate thoracotomy as definitive management of cardiac tamponade when a qualified surgeon is present.[1,12] Once a mandatory skill taught in the ATLS® course, a recent change to the course now makes pericardiocentesis optional.[12]

The evidence supporting the utility of pericardiocentesis as a bridging adjunct in traumatic pericardial tamponade is limited (level of evidence, 4), originating mainly from retrospective case series published before the advent of FAST with significant selection biases.[13,14] A review of the literature regarding the use and effectiveness of pericardiocentesis in traumatic pericardial tamponade in the modern era is necessary to better define its current role in trauma care.

PATIENTS AND METHODS

All scientific publications discussing the use of pericardiocentesis after trauma were identified using PubMed, EMBASE, and MEDLINE. Search terms included *wounds and injuries*, *blast injuries*, *wounds–penetrating*, *wounds–blunt*, *pericardial tamponade*, *pericardiocentesis*, *pericardial effusion*, *treatment*, and *outcomes*. The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) was USED.[15,16] Once identified, articles were reviewed for relevance to the topic of pericardiocentesis and cardiac tamponade in trauma, then sorted and categorized according to levels of evidence identified in Wright's evidentiary table.[17]

Inclusion Criteria

All English-language publications in peer-reviewed journals from 1970 to 2011 were considered including human retrospective series, prospective series, cohort studies, randomized controlled trials, and animal studies. The primary study population must be diagnosed with or suspected of having acute pericardial tamponade within 24 hours from injury (blunt, penetrating, or blast). Full-text articles of eligible publications from peer-reviewed journals were reviewed for inclusion.

Exclusion Criteria

Case reports; non-English publications; primary study population including pericardial effusion caused by inflammatory, infectious, or neoplastic processes; delayed presentation following trauma (>24 hours after injury); and/or those that otherwise did not meet inclusion criteria were excluded from review.

All articles screened were tabulated as included or excluded. Once identified, articles were reviewed for relevance to the topic of pericardiocentesis and cardiac tamponade in trauma by two reviewers. Articles were included or excluded when there was concordance. In cases of discordance regarding inclusion, the article was adjudicated by the senior author for inclusion or exclusion. Articles were sorted into human and animal studies, then categorized according to levels of evidence identified in Wright's evidentiary table by two reviewers.[17] A summary of the relevant findings of each included

article and its evidence rating is presented in tabular fashion (Table 1). Data were abstracted and managed using a standard tool (Microsoft Excel Version 2007, Redmond, WA). χ^2 test was used where appropriate.

RESULTS

There were 135 abstracts identified from the initial search query. Of these, 108 abstracts did not meet inclusion criteria (Fig. 1). Twenty-seven publications met inclusion criteria and were reviewed. Twenty-two records were retrospective case series (Level 4 evidence), four records were retrospective cohort studies (Level 3 evidence), and one record was a prospective case control (Level 2 evidence) with significant limitations in methodology including incomplete reporting of patient outcomes and inclusion of patients with tamponade from reasons other than trauma (Table 1). Twenty-seven studies met criteria for evaluation. There were 2,094 patients with suspected cardiac tamponade and 605 patients who received pericardiocentesis. There were 2,028 penetrating injuries and 59 blunt injuries. Mechanism of injury was not clearly specified in seven patients.

There was a decrease during the four decades reviewed in the number of reports describing the use of pericardiocentesis in the trauma literature. Notably, the reported use of pericardiocentesis in the management of traumatic tamponade decreased from 45.9% of patients in the period 1970 to 1979 down to 6.4% of patients in the period between 2000 and 2010 ($p < 0.05$). Reported rates describing the use of pericardiocentesis as the sole intervention decreased from 13.7% in the period 1970 to 1979 to 2.1% in the period 2000 to 2010 ($p < 0.05$, Fig. 2*A*). Similarly, the rates of performing pericardiocentesis before thoracotomy also decreased from 31.3% in the period 1970 to 1979 to 4.3% in the period 2000 to 2010 ($p < 0.05$). Conversely, there was an increase in the overall rate of thoracotomy (including patients receiving previous pericardiocentesis) in patients from 74.1% of patients studied from 1970 to 1979 to 97.5% of patients from 2000 to 2010 ($p < 0.05$, Fig. 2*B*).

From the 27 included studies, there were 9 studies with survival data attributable to patients who received pericardiocentesis and/or thoracotomy (Table 1). Seven of these studies described penetrating chest injuries, and two described blunt chest trauma. A total of 764 patients were included. All pericardiocentesis were reported to be performed on patients with high clinical suspicion of pericardial tamponade owing to mechanism of injury or clinical findings consistent with cardiac tamponade physiology. Three-hundred eighty patients (49.7%) received pericardiocentesis. One-hundred fifty-eight (41.6%) patients received pericardiocentesis as the sole intervention. There were 534 patients (69.9%) who received thoracotomy. Of these patients, 310 (58.1%) had thoracotomy only, and 224 (41.9%) received pericardiocentesis then thoracotomy. Overall survival following pericardiocentesis when used alone or as a bridging intervention was 83.4% (n = 317). In patients receiving pericardiocentesis as the only treatment, survival rate was 91.8% (n = 145). In patients who received thoracotomy following pericardiocentesis, survival was 79.5% (n = 178), and in patients who only had thoracotomy only, the survival rate

TABLE 1. All Included Publications From 1970 to 2010

Author	Year	Journal	n	Type of Study	Level of Evidence
Beall et al.[5]*	1971	*Ann Thorac Surg*	66	Retrospective case series	4
Trinkle et al.[30]	1974	*Ann Thorac Surg*	45	Retrospective case series	4
Harvey et al.[31]*	1975	*S Med J*	34	Retrospective case series	4
Mattox et al.[32]*	1975	*Circulation*	350	Retrospective case series	4
Symbas et al.[13]*	1976	*Ann Surg*	98	Retrospective cohort	3
Markovchick et al.[33]*	1977	*JACEP*	4	Retrospective case series	4
Arom et al.[36]	1977	*Ann Thorac Surg*	50	Retrospective case series	4
Szentpetery et al.[42]	1977	*J Trauma*	30	Retrospective case series	4
Evans et al.[43]	1979	*Ann Surg*	46	Retrospective case series	4
Kaushik et al.[57]*	1979	*J Cardiovasc Surg*	15	Retrospective case series	4
Breaux et al.[14] *	1979	*J Trauma*	197	Retrospective cohort	3
Trinkle et al.[37]	1979	*J Trauma*	100	Retrospective case series	4
Demetriades and van der Veen[44]	1983	*J Trauma*	125	Retrospective case series	4
Demetriades[38]	1984	*Br J Surg*	45	Retrospective case series	4
Demetriades[39]	1985	*Ann Surg*	70	Retrospective case series	4
Osinowo et al.[53]*	1986	*Injury*	3	Retrospective case series	4
Moreno et al.[58]	1986	*J Trauma*	100	Retrospective case series	4
Peper et al.[59]	1986	*Am Surg*	40	Retrospective case series	4
Leavitt et al.[60]*	1987	*Ann Thorac Surg*	3	Retrospective case series	4
McFarlane et al.[40]	1990	*W Indian Med J*	33	Retrospective case series	4
Kato et al.[61]	1994	*J Trauma*	33	Retrospective case series	4
Fulton et al.[50]	1998	*S Afr J Surg*	7	Retrospective case series	4
Thourani et al.[8]	1999	*Am Surg*	192	Retrospective cohort	3
Harris et al.[51]	1999	*Ann Thorac Surg*	128	Retrospective cohort	3
Harris et al.[52]	2001	*S Afr J Surg*	191	Retrospective case series	4
Gao et al.[55]	2004	*World J Surg*	82	Retrospective case series	4
Kurimoto et al.[54]	2006	*J Trauma*	7	Prospective case control	2

*Publications with survival data of patients who received pericardiocentesis and/or thoracotomy; n, denotes number of total patients included in each article.

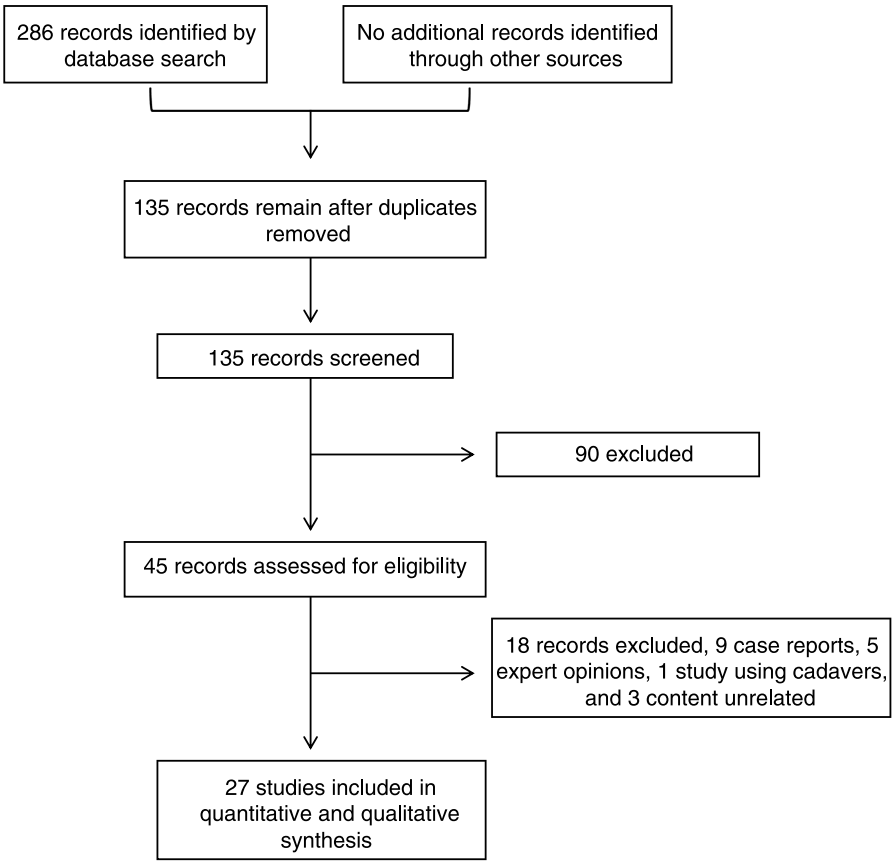

Figure 1. Flow chart.

was 58.7% (n = 192). The overall survival rate for all patients who underwent thoracotomy with or without previous pericardiocentesis was 74.9% (n = 400, Fig. 3).

DISCUSSION

The lethality of chest injuries has been understood since ancient times with eloquent descriptions of thoracic trauma detailed by Homer in his epic poem, the Iliad.[18] Of the 151 individual injuries described in the Iliad, 54 involved the chest, including 1 dramatic description of an exsanguinating penetrating cardiac wound.[18] Detailed review of these thoracic injuries demonstrated 70% mortality, further suggesting a clear understanding of the mortal consequences of chest trauma.[19]

Beck[20,21] classically described the evolution in the management of cardiac injuries as a progression from the uniformly fatal wound in the period of mysticism, through a period of observation and experimentation and eventually into the era of direct suture repair beginning in 1882. Consistent through these periods and into modern surgical practice is a controversy regarding the appropriate management of traumatic cardiac tamponade.[22,23]

The first description of traumatic cardiac tamponade is credited to Morgagni in 1761 who observed that injury to a coronary artery results in hemorrhage into the pericardial sac and subsequent compression of the heart.[22] Open surgical drainage of the pericardium was described in 1810 by Larrey, but the technique was initially met with great opposition. Of note, Billroth wrote in 1875: "Paracentesis of the pericardium is an operation which, in my opinion, approaches very closely to that kind of intervention which some surgeons would term a prostitution of the surgical act and other madness."[20,22,24]

The absolute certainty of suppurative bacterial infection following open pericardial drainage in the preantiseptic era mandated development of a blind percutaneous pericardial drainage procedure.[22,24] The first to successfully perform this procedure was Frank Schuh in 1839, and by 1915, blind pericardial puncture became the standard of care for pericardial effusions.[24]

For traumatic cardiac tamponade, thoracotomy with open pericardial drainage was the favored approach despite an associated 50% mortality. However, in 1943, Blalock and Ravitch[25] published a series of cases describing the use of pericardiocentesis in managing cardiac injuries in American soldiers during World War II. They proposed that nonoperative management in select cases may reduce the significant mortality associated with operative intervention for cardiac injuries. The authors concluded that in patients whose symptoms are caused by tamponade alone without evidence of active bleeding, percutaneous aspiration of the pericardium may be performed and repeated once for recurrence. However, operative intervention was mandatory with a second recurrence.[25] Their initial report was followed in the postwar period, with a report documenting seven consecutive civilian patients with

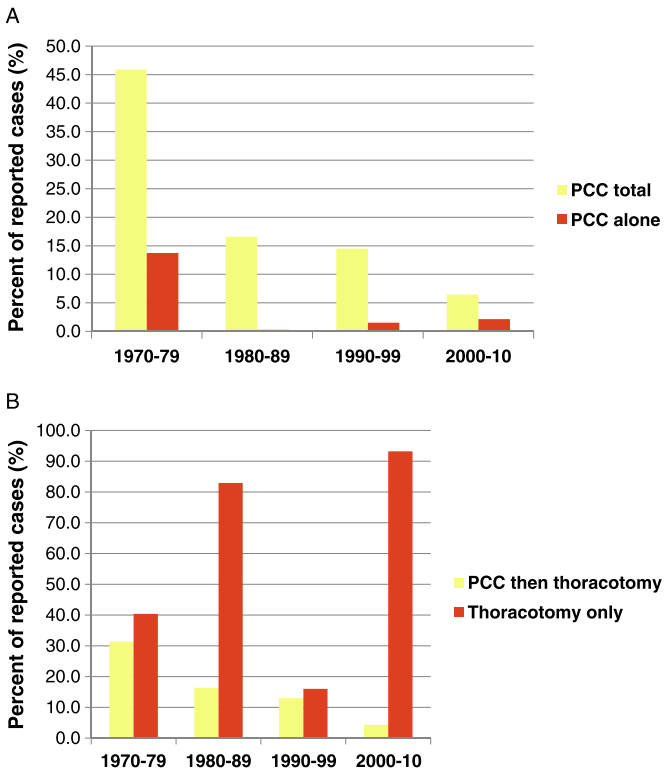

Figure 2. *A,* The rates of all reported use of pericardiocentesis with or without subsequent thoracotomy. *B,* The rates of reported use of pericardiocentesis before thoracotomy and thoracotomy alone during the four decades reviewed.

traumatic cardiac tamponade successfully managed with pericardiocentesis as the sole intervention.[26] Thereafter, pericardiocentesis was regarded as a critical therapeutic and diagnostic tool for traumatic pericardial tamponade.

Following the work of Blalock and Ravitch, there was great initial enthusiasm for pericardiocentesis evidenced by the relatively large numbers of retrospective studies published on the effectiveness of pericardiocentesis for both diagnosis and therapy.[5,13,14,25–33] These studies were limited by their largely retrospective nature with methodological limitations in terms of their inclusion criteria, treatment thresholds, and limited report on outcomes. Technical advances in anesthesiology, cardiac surgery, and the introduction of resuscitative thoracotomy for specific patients with penetrating chest trauma allowed Beall[5] in 1971 to report on resuscitative thoracotomy without pericardiocentesis as a satisfactory method of management for penetrating cardiac injury.[23,27]

The decreasing numbers of publications describing pericardiocentesis for traumatic pericardial tamponade since 1970 reflects the changing trends in management as a result of these advances in care (Table 1). In addition, in the 27 publications describing the use of pericardiocentesis in traumatic pericardial tamponade from 1970 to 2010, there was a dramatic decrease in the rate of pericardiocentesis use with a zconcurrent increase in rate of thoracotomy (Fig. 2*A* and *B*). Regarding survival in the studies reviewed, patients who received pericardiocentesis as a sole or bridging intervention demonstrated an overall survival rate of 83.4% (Fig. 3), and those patients receiving only pericardiocentesis and no other surgical intervention experienced a remarkable 91.8% survival rate. In comparison, the overall survival rate for patients who had thoracotomy following pericardiocentesis was significantly higher than those patients who had thoracotomy only (79.5% and 58.7%, respectively) (Fig. 3). Interpretation of these results is challenging, given the varying severity of reported cases, differences in follow-up periods, small case numbers, selection bias, and lack of adequate control groups. Those patients who did not receive pericardiocentesis and proceeded directly to thoracotomy and those requiring thoracotomy after initial pericardiocentesis were likely more severely injured than those who received pericardiocentesis as a sole intervention. Furthermore, the exact number and outcomes of patients who received resuscitative emergency department thoracotomy was not consistently reported. The inherent high mortality associated with emergency department thoracotomy certainly contributed to the lower thoracotomy-only survival rate. Therefore, the differences in the thoracotomy and pericardiocentesis mortality rates are invalid in terms of comparing their individual efficacies. However, these findings do demonstrate the lifesaving effect pericardiocentesis can provide when performed in the appropriate trauma setting.

While pericardiocentesis has been recognized as a critical skill in the ATLS® course since its inception, there have also been a significant number of reports during the last 40 years commenting on its unreliable nature for both diagnosis and therapy in traumatic pericardial tamponade. Most criticism against its use lies in the high false-negative aspiration rate attributed to the formation of clotted blood or semisolid coagulum within the pericardium, the potential for severe iatrogenic injury (myocardial, abdominal, arterial, and lung injuries), and substantial data demonstrating improved survival rates with early primary thoracotomy for penetrating chest injuries.[29,34–41] Concurrently, with the introduction of ultrasound in the mid-1980s followed by the introduction of the FAST examination, ultrasonography quickly became a diagnostic modality of choice for traumatic tamponade. FAST has now largely replaced pericardiocentesis in trauma patients as a diagnostic modality, thereby avoiding potentially severe iatrogenic complications and life-threatening delays in definitive surgical treatment associated with pericardiocentesis.[2,30,37–40,42–47] Notably, one prospective study using cadavers to assess the safety of four common techniques for pericardiocentesis found the highest number of potentially severe

	n	% Survival
Total PCC	380	83.4
Total thoracotomy	534	74.9
PCC only	158	91.8
PCC + Thoracotomy	224	79.5
Thoracotomy only	310	58.7

Figure 3. Proportion of patients who survived after receiving pericardiocentesis with or without subsequent thoracotomy and thoracotomy alone.

iatrogenic injuries (abdominal and diaphragmatic injury) occurred when using the method taught by ATLS®.[41] Currently, the trend continues to veer away from the use of pericardiocentesis in trauma and emphasizes early thoracotomy for penetrating chest wounds, with many surgeons abandoning the practice altogether, preferring instead to use the FAST examination, mechanism of injury, and clinical evaluation to determine when immediate operative intervention is needed.[47–49]

Evaluation of the effectiveness and utility of pericardiocentesis in underdeveloped countries remains inconclusive with the data presented in this review. From the 27 included publications, 9 nine publications were conducted outside of the United States. The countries represented in these nine studies were South Africa,[38,39,44,50–52] Nigeria,[53] Jamaica,[40] Japan,[54] and China.[55] From these countries, only Nigeria is considered underdeveloped using income as a metric according the World Health Organization.[56] These nine studies contributed only 57 patients of the 605 total patients who received pericardiocentesis. Of these 9 publications, only the publication originating from Nigeria, which included one patient who received pericardiocentesis was included in the survival analysis. Thus, the lack of adequate representation in the literature reviewed regarding the practice and outcomes of pericardiocentesis in underdeveloped nations prevents making conclusions regarding the need for mandatory pericardiocentesis to be taught in international ATLS® courses. The utility of pericardiocentesis as a diagnostic modality for traumatic tamponade seems to have essentially disappeared in the current era of rapidly available and accurate ultrasonographic examinations. The remarkably high survival rates found in this review in patients who received pericardiocentesis alone and as a bridging intervention certainly reflect a significant selection bias. To objectively review the efficacy and outcomes of pericardiocentesis in the trauma population, a review of the National Trauma Data Bank is currently underway. However, data from this review do indicate that when used in the correct situation by an experienced operator, pericardiocentesis can be a lifesaving maneuver. Thus, it seems that there remains a role for pericardiocentesis in the modern trauma system, specifically in the rural/underserved setting where a critically injured patient demonstrates tamponade physiology with no immediate qualified surgeon available. In this scenario, pericardiocentesis potentially can provide a lifesaving bridging therapy to definitive surgical intervention. We conclude that there is a role for pericardiocentesis in nontrauma centers where definitive surgical management is not immediately available and transport time to a higher level of care facility supports the use of temporary decompression by pericardiocentesis. However, trauma systems must also weigh the inherent risks associated with pericardiocentesis and the frequency with which their nontrauma center providers will use this intervention when considering inclusion in their training programs.

AUTHORSHIP

T.H.L., J.-F.O., M.A.S., and J.B.K. provided the study concept. T.H.L., J.-F.O., and M.C. performed the acquisition of data. T.H.L., J.-F.O., M.C., M.A.S., and J.B.K. performed the analysis and interpretation of data. T.H.L., J.-F.O., M.C., M.A.S., and J.B.K. drafted the manuscript. T.H.L., J.-F.O., M.C., M.A.S., and J.B.K. provided critical revision of the manuscript for important intellectual content.

DISCLOSURE

The authors declare no conflicts of interest.

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