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REVIEW ARTICLE

Pooled preventable death rates in trauma patients

Meta analysis and systematic review since 1990

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Abstract
Purpose To estimate the pooled PDRs (preventable death rates) with articles being published since 1990, and compare the differences of PDRs over time and according to the evaluation approaches to determine preventable deaths.
Methods Articles concerning preventable deaths of trauma patients published between 1990 and 2013 were systematically reviewed, and the pooled PDRs with 95 % confidence intervals were estimated using meta-analysis. It was also observed whether the PDRs differed over time and according to the evaluation approaches employed for determining preventable deaths.
Results Twenty seven articles were identified through bibliographic searches using PUBMED with the keywords of 'preventable deaths', 'the cause of deaths' and 'trauma'. Mean ages of the trauma patients in the selected articles ranged from 32.9 to 58 years old and 72 % were male on average. The pooled PDR was estimated as 0.20 with 95 % CI (0.16, 0.25) with a p-value of 0.0001, and the differences of PDRs over time and according to the employed approaches were not statistically significant with p-values of 0.06 and 0.99, respectively. However, PDRs determined by statistical approaches alone showed greater dispersion in comparison with the 'panel review approach'.
Conclusions This article provided some insights about the trauma care system by computing the pooled estimate of PDRs over the past 23 years as an indicator. The pooled PDR was estimated as approximately 20 %, with no statistical significance of differences in PDRs over time or by the evaluation methods employed. That left us still room for improvement in trauma care system despite our efforts to reduce PDRs. In addition, when 'statistical approaches' are applied alone to estimate PDRs, we recommend that statistical methods should be applied with caution when the characteristics of trauma patients are heterogeneous. The optimal approach might be to combine both statistical and panel review approaches instead of employing a single approach.

Keywords Preventable · Deaths · Trauma · Causes of deaths

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Introduction

Trauma is one of the leading causes of deaths worldwide [23]. As a result, many physicians are aware of the importance of the trauma care system, and study the causes of deaths in order to improve outcomes in the traumatic care setting. Preventable deaths imply that the patient could have survived under optimal treatment conditions in the optimal trauma care system. However, it is difficult to define the optimal care and to determine 'avoidable' or 'preventable' deaths. Generally, deaths resulting from trauma are classified as 'immediate death', 'early death', and 'late death' according to the time from the occurrence

of trauma to the time of death. Among these, preventable death seems to be most closely related to 'early death' where early death occurs in the first 6 h as a result of evolving conditions or complications such as hemorrhagic injuries [9, 23]. Accordingly, preventable deaths can occur in either the pre-hospital stage or hospital stage. Physicians report preventable death rates (PDRs) in an attempt to diagnose or improve the trauma care system including the emergency care system. However, PDRs vary widely among articles. We systematically reviewed articles about PDRs published for the period of 1990–2013, and estimated the pooled PDRs. In addition, we provided some insights about PDRs by statistically analyzing the studies on the selected articles using meta-analysis.

Methods

As shown by Fig. 1, articles were identified through bibliographic searches using PUBMED based on the following inclusion criteria: articles were restricted to those published in English since 1990 reporting preventable deaths with trauma patients; trauma, preventable, deaths and cause of deaths were used as keywords; clinical articles using animals and articles relating to combat were excluded; and book chapters and literature reviews were also excluded.

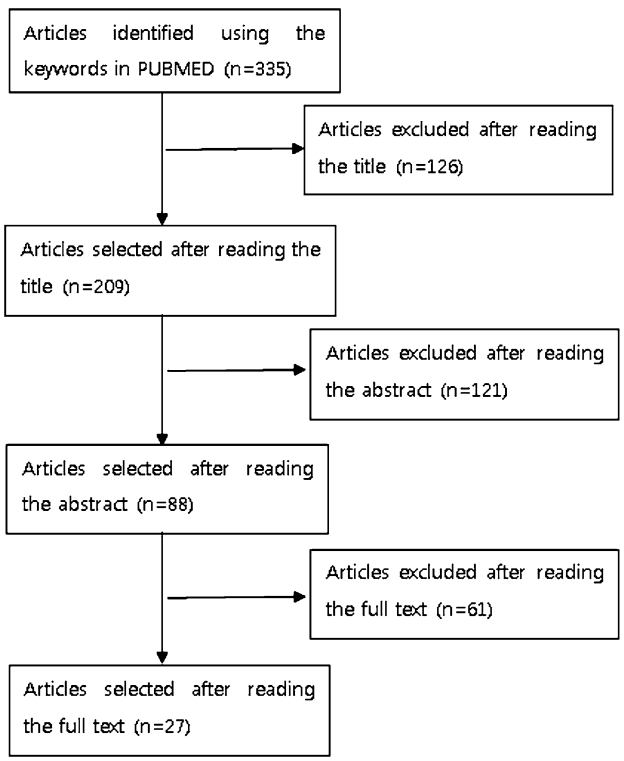


Fig. 1 Article selection procedure

According to systematic searches in Fig. 1, a total of 27 articles were selected which were published in 14 different countries, and they are summarized in Table 1. Most studies (85.2 %) involved the collection of data retrospectively, and common sources of data were pre-hospital records, hospital medical records and autopsy results. The target populations of all articles except one were adult trauma patients whose mean ages ranged from 32.9 to 58 years old. The average proportion of male patients in the studies was about 72 %, and the sample sizes were distributed from 13 to 2,081. The study periods ranged from three months to nine years. Preventable deaths were evaluated by multidisciplinary panel review (55.6 %), statistical approaches such as Ps (probability of survival) (3.7 %; [21]) and mixed approaches of those two. The trauma patients in [21], which only used Ps, were solely based on severe brain injury patients. Some articles (29.6 %) evaluated the preventability of traumatic deaths using panel reviews but also computed Ps using TRISS [trauma and Injury severity score (ISS)] [13, 20, 26, 27] or ASCOT (A severity characterization of trauma) [27]. Boman et al. [2], Ince et al. [15] and Ashour et al. [1] used the ISS or AIS (abbreviated injury scale) scale instead. In Table 2, the PDRs were computed by dividing the number of preventable deaths by the number of total deaths, and the counts of the preventable deaths in this article were computed by adding the counts of 'preventable death' to the counts of 'potentially preventable death'.

Results

Pooled estiamtes of PDRs

In Table 2, PDRs were widely distributed from 2.5 to 58.5 %, and sample sizes varied from 13 to 2,081. McDermott et al. [20] compared two datasets having separate study periods of (1997–1998) and (2002–2004), and we considered PDRs associated with each study period separately in data synthesis, marked as McDermott et al.[1] and McDermott et al.[2] in Fig. 2. Considering all 28 studies, we estimated the pooled PDR by meta-analysis. The estimated pooled PDR was 0.20 with a 95 % confidence interval (0.16, 0.25) based on the random effect model to take into consideration the variability of the studies. The pooled variance between the studies (τ^2) was computed by DerSimonian and Lairds estimation. Z-statistics to test the significance of the estimated PDR and determined it to be statistically significant with the p-value of less than 0.0001.

Difference of PDRs over time

Boman et al. [2] determined the decrease in PDRs over time using the proportion of preventable deaths during the

Table 1 Articles included in the analysis

References	Year	Study Design	Study Period	Setting	Location
Cayten et al. [4, 5]	1991	Retrospective	1987–1989	Hospital	NY, USA
Davis et al. [11]	1991	Retrospective	1985–1988	Hospital	San Diego, USA
Caldwell et al. [3]	1993	Retrospective	1986–1990	Hospital	Dublin, Ireland
Thoburn et al. [29]	1993	Retrospective	1989–1991	Hospital	Florida, USA
Yates et al. [32]	1993	Retrospective	1992	Hospital	UK
Maio et al. [18]	1996	Prospective	1994	Hospital	Michigan, USA
Sugrue et al. [27]	1996	Retrospective	1991–1992	Hospital	Sydney, AU
Gorman et al. [13]	1996	Retrospective	1989–1990	Both	North Wales, UK
Papadopoulos et al. [22]	1996	Retrospective	1991–1992	Pre–hospital	Piraeus, Greece
Iau et al. [14]	1998	Retrospective	1993–1994	Hospital	Singapore
Boman et al. [2]	1999	Retrospective	1988–1996	Hospital	Sweden
Esposito et al. [12]	1999	Retrospective	1989–1992	Hospital	Montana, USA
Chiara et al. [9]	2002	Retrospective	1997–1998	Both Milan, Italy	
Zafarghandi et al. [33]	2003	Retrospective	–	Both	Tehran, Iran
Shanti et al. [26]	2003	Retrospective	1996–2001	Hospital	Detroit, USA
Ince et al. [15]	2006	Retrospective	2000–2002	Hospital	Istanbul, Turkey
Ashour et al. [1]	2007	Retrospective	2003	Pre–hospital	Victoria, AU
Martine et al. [19]	2007	Retrospective	–	Hospital	Akron, USA
McDermott et al. [20]	2007	Retrospective	1997–1998	Both	Victoria, AU
			2002-2004	Both	Victoria, AU
Teixeira et al. [28]	2007	Retrospective	1998–2005	Hospital	LA, USA
Tien et al. [30][b]	2007	Retrospective	1999–2003	Hospital	Canada
Chua et al. [10]	2009	Prospective	2006	Hospital	Sydney, AU
Saltzherr et al. [24]	2011	Retrospective	2006–2007	Hospital	Netherlands
Sanddal et al. [25]	2011	Retrospective	2005	Both	Utah, USA
Wilson et al. [31]	2011	Prospective	2008–2009	Both	Sao Paulo, Brazil
Kleber et al. [17]	2013	Prospective	2010	Pre–hospital	Berlin, Germany
Moon et al. [21][a]	2013	Retrospective	2011	Hospital	Chonnam, Korea

[a] Only includes severe neuro-trauma patients

[b] Only computed hemorrhagic death

period of 1988–1996 in Sweden. We studied whether the same trend existed in the selected articles. Two articles whose study periods were unavailable [19, 33] were excluded from this analysis. Accordingly, 26 studies were categorized into two groups based on the median years of the study periods. The first group consisted of 15 articles (57.7 %) with a median study years of 1990–2000. The other 11 articles (42.3 %) were assigned to the second group whose median study years were 2000–2013. We statistically tested whether the PDRs were different between these two groups: the PDRs were estimated to be 0.24 with 95 % CI (0.01, 0.18) for the first group and 0.16 with 95 % CI (0.09, 0.22) for the second group (Fig. 3). The results showed that the PDRs were lower in the more recent studies, but the difference was not statistically significant with a p-value of 0.06 by Q-test. We also tested the time effect on PDRs using a regression approach and found that the effect was not statistically significant with a p-value of 0.77.

Difference in PDRs related to the employed evaluation approaches

Three approaches were employed to determine preventable deaths in the selected articles: (1) expert panel review, (2) statistical methods, and (3) a mixed approach which used both (1) and (2) together. More than half of the articles (57.1 %) chose a panel review approach to identify the preventable deaths, and the panels were generally composed of multidisciplinary team members including two to three trauma surgeons. The second most frequent approach (28.6 %) was the mixed approach combining a panel review with any type of statistical method. However, preventable deaths were typically

Table 2 Summary information about PDRs

References	Male (%)	Mean age (years)	Evaluation methods	TD	PD	PDR (%)
Cayten et al. [4, 5]	*	52.1	Mixed	421	233	55.3
Davis et al. [11]	*	*	Expert panel review	813	62	7.6
Caldwell et al. [3]	*	43	Expert panel review	28	9	32.1
Thoburn et al. [29]	68.1	40.3	Expert panel review	232	10	4.3
Yates et al. [32]	*	*	Mixed	508	171	33.0
Maio et al. [18]	71.6	37.4	Expert panel review	155	20	12.9
Sugrue et al. [27]	36.7	*	Mixed	38	6	15.8
Gorman et al. [13]	*	*	Mixed	307	45	14.7
Papadopoulos et al. [22]	79.3	44.46	Mixed	82	39	47.5
Iau et al. [14]	81.2	*	Expert panel review	85	19	22.4
Boman et al. [2]	73	58	ISS $\leq$35 and AIS_h <4	335	70	20.9
Esposito et al. [12]	*	12	Expert panel review	138	12	9.0
Chiara et al. [9]	73.0	44.0	Expert panel review	203	87	42.9
Zafarghan et al. [33]	90.0	*	Expert panel review	69	21	30.4
Shanti et al. [26]	*	*	Mixed	281	45	16.0
Ince et al. [15]	78.1	32.9	ISS $\leq$14	160	4	2.5
Ashour et al. [1]	82.1	*	Medical records, ISS<50	112	5	4.5
Martine et al. [19]	*	*	Expert panel review	112	5	4.5
McDermott et al.[1]	70.0	43.2	Mixed	245	88	36.0
McDermott et al.[2]	69.0	46.0	Mixed	193	54	28.0
Teixeira et al. [28]	66.7	40.0	Expert panel review	2,081	51	2.5
Tien et al. [30]	*	48.7	Expert panel review	86	14	16.0
Chua et al. [10]	73.3	39.0	Expert panel review	13	1	7.7
Saltzherr et al. [24]	66.0	49.3	Expert panel review	62	18	29.0
Sanddal et al. [25]	70.0	43	Expert panel review	434	27	6.7
Wilson et al. [31]	83.6	39.0	Autopsy review	416	55	13.2
Kleber et al. [17]	69.7	53.0	Expert panel review	264	40	15.2
Moon et al. [21]	73.8	*	TRISS	53	31	58.5

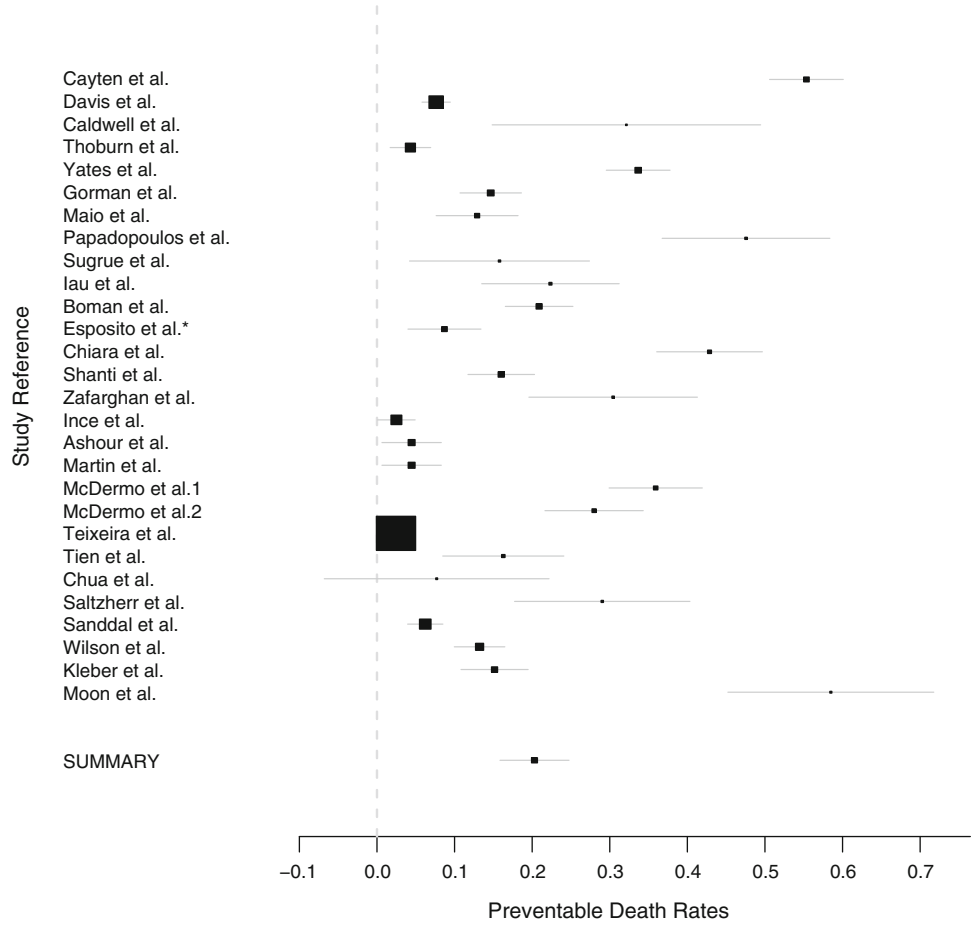
AIS_h AIS score based on head injuries, *TD* total number of deaths, *PD* the number of preventable deaths, *PDR (%)* PDRs

determined by panel review on the mixed approach, and the statistical methods were employed to filter the deaths which were examined. The remaining articles (14.3 %) applied any type of statistical methods to define the preventable deaths such as TRISS, ASCOT or ISS severity score. We categorized the articles into two groups: the first group included the articles using either 'panel review approach' or 'mixed approach', and the second group included those using the 'statistical approach'. The pooled PDRs were estimated as 0.21 with a 95 % CI (0.16, 0.26) for the first group and as 0.19 with a 95 % CI (0.07, 0.32) for the second group. The difference in PDRs between the two groups was tested using Q-test and found to be not statistically significant with a p-value of 0.99. However, it should be noted that the dispersion of PDRs was approximately three times wider in the statistical approach group than in the panel review group shown by Fig. 4.

Discussion

Some articles differentiated 'preventable deaths' from 'potentially preventable deaths' according to the severities of the injuries [11, 14], but we treated them collectively as 'preventable deaths' in the analysis. The preventable deaths were conditioned on two in [11]: (1) injuries or sequelae considered (severe but) survivable or (2) (suspected) errors in care which implicated directly or indirectly in the patient's demise. Reported factors contributing to preventable deaths were diverse according to the mechanisms of the injuries. Most categories referred to in preventable deaths were diagnostic errors, missed injuries, delay in transfer or inadequate care [14]. Accordingly, the PDRs might be regarded as an indicator of the quality of the trauma care system. However, the range of PDRs across articles varied widely, and the evaluation approaches, sample size, study locations and study periods were also

Fig. 2 Pooled PDRs



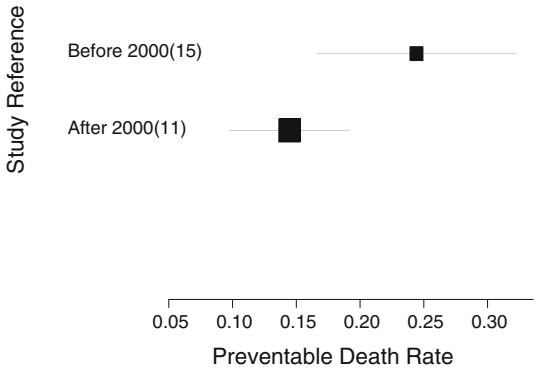


Fig. 3 Difference of PDRs by years

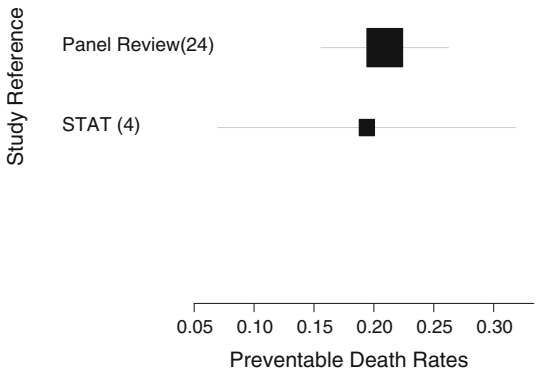


Fig. 4 Difference of PDRs by the evaluation methods

significantly different across the studies. These factors led us to question the external validity of PDRs. Because of these reasons, we systematically searched articles being published since 1990 through PubMed, and selected 27 articles for further studies. With the selected articles, we examined: (1) the representative measure of PDRs; (2) whether PDRs changed over time; and (3) whether PDRs were affected by the evaluation approach which was employed to determine the preventable deaths. We addressed these questions by conducting meta-analysis of the article data and testing for statistical significance controlling alpha at a level of 0.05. The pooled estimate of the PDRs was approximately 20 % on average over the period 1990–2013. When we compared the difference in PDRs between the periods of (1990–2000) and (2000–2013), the difference was not statistically significant with a *p*-value of 0.06 although the proportion of preventable deaths was lower in more recent years (which was similar to [2]). To

eliminate the evaluation approach as a confounder in our analysis, the difference was also analogously tested with articles which only used the 'panel review approach'; however, the test result did not change with a p-value of 0.17. The analysis results implied that there might still be room for improvement in the trauma care system despite significant efforts. The difference in PDRs using different evaluation approaches was not statistically significant with p-value of 0.98. Namely, PDRs were not affected by the employed approach to identify the preventable deaths. Some articles favored the 'panel review approach' over the 'statistical approach', but panel review could over-inflate the PDRs [16]. In the panel review approach, there was no gold standard for the optimal make up of panels or 'how to reach a decision evaluating preventable deaths'. However, most articles using a panel review approach constitued 'multidisciplinary team', and some even used autopsy reports to make a decision. Those efforts might prevent PDRs from over-flating by incorporating various points of views in a panel review approach. Some articles criticized 'statistical approach'. TRISS was prevalently used, but it was criticized because of its wide variation in mortality prediction when the trauma types were broad [4, 6, 7, 8]. Conversely, Moon et al. [21] supported the use of Ps in mortality using TRISS. When we compared the difference in PDRs according to the employed approach, PDRs estimated by the 'statistical approach' were about three times wider in dispersion compared with the 'panel review approach'. The wider dispersion of PDRs could be attributed to the variability of trauma deaths across the studies in agreement with the findings about the 'statistical approach' of Cayten et al. [5]. It is also plausible that Moon et al. [21] applied TRISS to predict the mortality with only neurotrauma patients, and TRISS worked well. Yet, Shanti et al. [26] demonstrated that the 'statistical approach' resulted in a consistent trend: the higher Ps, the more likely the death was found to be preventable. It appeared that there was no superior approach for PDR estimation. Thus, we need to select the evaluation approach with caution. In the case of a panel review approach, it is important to carefully select the make up of the multidisciplinary panel to determine the preventable deaths without bias. When a 'statistical approach' was applied as a stand-alone method, we need to first consider the types of trauma patients evaluated so as not to broaden the dispersion of PDRs. If the majority of trauma patients had multiple injuries or trauma characteristics are heterogeneous, a 'statistical approach' might serve as a good diagnostic filter within a 'panel review approach', but the estimate of PDR might not be accurate enough to make an inference because of the higher dispersion. Generally, it might be more suitable to combine a 'panel review' with a 'statistical approach' rather than to choose either one.

Conclusion

As an indicator to diagnose the quality of the trauma care system, we estimated the pooled PDR with articles published from 1990 to 2013 using meta-analysis. As a result, the estimate of PDRs was computed as about 20 %. More recent articles reported slightly lower PDRs, but the decrease in PDRs over time was not significant, which suggests that additional effort is needed to reduce PDRs by improving the trauma care system. In addition, we tested the difference in PDRs according to the selected evaluation approach and also determined that the differences were not significant. However, we need to carefully consider the most accurate approach to determine preventable deaths. When applying a 'panel review approach', we need to carefully select a multidisciplinary panel so that various viewpoints are reflected. When a 'statistical approach' is applied, we need to select patients whose trauma types are as similar as possible to avoid broadening the confidence intervals of PDRs. Most of all, it might be optimal to find the cross-point of the two approaches by combining both approaches instead of choosing a single approach.

Conflict of interest None.

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