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Military thoracic gunshot wounds: A systematic review

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Abstract: A systematic review of the literature was carried out using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method to investigate the frequency of military thoracic gunshot wounds (GSWs) and deaths in combat theatres since World War Two (WW2). An electronic database search of World of Science, Scopus, Science Direct, PubMed and Microsoft Academic was conducted using the keywords ‘combat, casualties, thorax, gunshot, and military’ to identify peer-reviewed journals and conference papers on the topic. Twenty-three sources relevant to this review were identified and covered multiple theatres of operation. While there is a downward trend in the frequency of thoracic GSWs and fatalities likely due to the improvement of body armour, the improvement in medical treatment and increased frequency of improvised explosive devices (IEDs), the review shows that the advancement has not removed the likelihood of thoracic GSWs, which still accounted for approximately 15% of all thoracic injuries in the most recent combat theatres. The systematic review identifies that GSWs of the thorax continue to be a risk in military theatres and therefore, medical personnel should be aware of the frequency and severity of thoracic GSWs and should be prepared to treat these life-threatening injuries, as timely intervention is essential.

Keywords: military, thoracic, gunshot, systematic review

1 Introduction

Gunshot wounds (GSWs) are a source of severe traumatic injuries and accounted for 31% of military fatalities

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of UK soldiers from January 2009 to December 2013 (Penn-Barwell et al. 2016).

The thoracic cavity contains vital organs such as the heart, lungs and major arteriovenous structures and is protected by the thorax, which is made up of the thoracic spine, the rib cage and the sternum; and the diaphragm separates the thorax from the abdomen. The total body surface area of an adult’s thorax is approximately 18% (Moore et al. 2019). Historically, in combat theatres, thoracic GSWs accounted for a large proportion of mortality and morbidity. In more recent combat theatres, the thorax has remained a preferred target, thought to be due to its large surface area and vital internal organs. Therefore, protecting the thorax from penetrating injury remains of critical importance in austere environments.

The recognition of the importance of protecting the thorax has driven the evolution of body armour. During World War One (WW1) and World War Two (WW2), body armour was not worn; in the Korean and Vietnam wars flak vests were introduced; and more recently, thoracic protection has advanced to the capacity of defeating 7.62 mm calibre ammunition and in some cases armour-piercing ammunition.

However, like the evolution between predator and prey, munition design has evolved to combat advances in body protection. Nowadays, munitions include enhanced penetration projectiles to overcome body armour. Therefore, despite advances in body armour, GSWs of the thorax remain a common injury.

This systematic review aims to investigate military thoracic GSW frequency and subsequent fatalities reported since WW2, and to inform and direct future research in crucial areas such as medical treatment and protection.

2 Method

A systematic review of the English literature concerning military thoracic GSWs and fatalities was carried out by two separate researchers following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. An electronic database search of

World of Science, Scopus, Science Direct, PubMed and Microsoft Academic was conducted using the keywords ‘combat, casualties, thorax, gunshot, and military’ to identify peer-reviewed journals and conference papers on the topic. The reference lists from the included studies were searched to identify additional studies.

The inclusion criteria were: (1) Reporting on military (combat) casualties; (2) Gunshot injuries; (3) Anatomical region described as the thorax, chest or back if it pertained to the thoracic region; (4) Minimum of one casualty or fatality from a thoracic gunshot; (5) Reported since WW2; (6) Written in English. Exclusion criteria were: (1) Non-gunshot trauma to the thorax; (2) Civilian gunshot injuries; (3) Unable to distinguish between mechanisms of penetrating injury; (4) Reported before WW2.

The primary outcome of this review was to determine the frequency of thoracic GSWs and fatalities in military personnel.

The modified Newcastle–Ottawa scale was used to determine the methodological quality and focused on evaluating if the study was representative of the exposed cohort, the method of ascertaining exposure data, the degree of comparability of the data and whether an assessment of the outcome was presented and quality ratings given (poor, fair or good). The modified Cochrane tool was used to assess the risk of selection, performance, detection, attrition and reporting bias of the included studies with each metric given a risk of bias score (low, medium and high) and the scores totalled to determine the overall risk of bias.

The risk of population bias in this systematic review is expected due to the military hospitals also treating

civilians; therefore, power analysis was not performed. However, a narrative description of the theatre and injury occurrence was performed to reduce the possible effects of study overlap. Qualitative synthesis in clinical outcome was not included in this systematic review due to the lack of long-term outcomes and severity.

The studies were further reviewed to determine the dates and the location of the combat theatre reported, the population involved, the number of thoracic GSW, the percentage of GSW the thorax accounted for or alternatively the percentage of thoracic injuries that GSW accounted for, the number and/or percentage of fatalities from thoracic GSW and any pertinent remarks to the study.

3 Results

The search criteria identified 224 articles, including 218 journal articles, one report, one conference proceeding and four chapters from one book. After implementing the inclusion and exclusion criteria, 23 studies were included for final review. Most data sources were discarded due to their datasets not differentiating between body areas and/or between the mechanism of injury, with penetrating injury used to classify both explosive fragmentation and gunshot injury. No other systematic reviews on this subject were identified. (Figure 1).

The quality of the studies was predominantly fair (10/23), with the remaining studies being split between poor (5/23) and good (8/23) quality. However, due to the lack of detail in some population descriptions between military and civilians, and differences in data reporting,

Fig. 1: PRISMA flow diagram.

the majority of studies have been classified as having an unclear risk of bias (16/23), with the remaining studies being split across a low risk of bias (4/23) and a high risk of bias (3/23). This essentially means that most of the studies are missing information which makes the studies difficult to assess.

When comparing the studies that had a low risk of bias, the data showed an exponential downward trend in the frequency of thoracic GSW before levelling off and a decrease in the percentage of fatalities from thoracic GSW, as can be seen in Figure 2. This frequency of casualties reduces from 18 casualties per month from thoracic GSW (rounded to nearest casualty) and 57.1% fatalities in New Georgia – Burma to 1 casualty per month (rounded to nearest casualty) and 27% fatalities in Iraq and Afghanistan. If this analysis is extended to include studies that had an unclear risk of bias, when using data sets that can be compared, the downward trend in fatalities can still be seen; however, this is not as clear in the frequencies of casualties (see Figure 3). Unfortunately, it was not possible to include all studies with an unclear risk of bias in this comparison due to the limited availability of data. This includes uncertainty if the number/percentage of fatalities is based on the number of gunshot fatalities that are attributed to thoracic GSW, or if they are based on the number of thoracic GSWs that were fatal and civilian injuries being included in the data set.

The studies included after the PRISMA process and data obtained for military, combat, thoracic gunshot injuries are summarised in Table 1.

4 Discussion

While the data is limited to only a small number of combat theatres and only provides information on specific nationalities and services, this is the first study to summarise and provide insight into the frequency of thoracic GSWs and subsequent fatalities over the last 80 years. The results of this study show that there is a clear downward trend in the percentage of fatalities and an exponential reduction in the frequency of casualties from thoracic GSW when considering studies that have a low risk of bias. These declines can be attributed to (a) the evolution of body armour, including the design, body surface coverage area and an improvement in body armour standards; (b) improvements in time of evacuation of casualties from the point of wounding to surgical care; and (c) improvement in medical techniques. Furthermore, the change in warfare giving way to asymmetric conflicts—which are characterised by the widespread use and increased frequency of improvised explosive device (IED) injuries rather than GSWs—will also have contributed to the decline in thoracic GSW.

Fig. 2: Frequency of thoracic gunshot injuries per month and percentage of fatalities from thoracic GSW for studies with a low risk of bias.

Fig. 3: Frequency of thoracic gunshot injuries per month and percentage of fatalities from thoracic GSW for studies with a low and unclear risk of bias.

4.1 The evolution of body armour and the subsequent effect it had on thoracic GSW

4.1.1 Body armour design

Body armour designs have changed significantly over the last 80 years from 1 mm thick manganese steel chest plates issued to Airborne forces in WW2, to M1952 flak jackets in Korea, followed by the M-69 Fragmentation Protective Body Armour in Vietnam and were continued to be worn during the start of the troubles in Northern Ireland (Tobin and Iremonger 2006; Carr and Lewis 2014). The M1952 and M-69 flak jackets did provide a certain level of protection against fragmentation and shrapnel; however, this level did not encompass protection against high-velocity projectiles, and therefore the frequency of thoracic gunshot injuries and the percentage of fatalities from thoracic GSW continued to remain high.

In 1965 para-aramid fibres were discovered and in 1972 they were commercialised by Dupont as Kevlar and were seen to offer ballistic protection from handguns. Para-aramids are still used in both military and police body armours today.

In the late 1970s the UK Forces were issued with Individual Northern Ireland Body Armour (INIBA), which not only offered protection from fragmentation and shrapnel but also protection against high-velocity projectiles using front and rear hard ceramic plates (Breeze et al. 2021). This would have led to reduction in the number of thoracic GSW and subsequent fatalities.

Meanwhile, the US military issued the Personal Armor System for Ground Troops (PASGT), which remained in service till the early 2000s. PASGT was designed to provide better protection against fragmentation and saw the move away from ballistic nylon to Kevlar by the US military (Roberts and Bullian 1993).

In 1991, the First Gulf War (GW1) saw Enhanced Combat Body Armour (ECBA) issued to UK Forces, which incorporated two ceramic hard armour plates with soft body armour (Carr and Lewis 2014). GW1 saw the widespread use of body armour for the first time with ECBA and PASGT being worn. (Brayley 2011).

In 2003 the US military issued Interceptor body armour (IBA), which consisted of an outer tactical vest that provided protection against fragmentation and handgun bullets, whilst the two Small Arms Protective Inserts (SAPI plates) provided protection up to 7.62 mm Full Metal Jacket (FMJ) bullets (Brayley 2011). The UK Forces continued to wear ECBA until 2006 and the introduction of OSPREY. The OSPREY plates provided better coverage and higher performance than the ECBA plates and provided an enhanced multi-hit capability, and the ECBA plates were repurposed as side plates to increase coverage area (Carr and Lewis 2014, Breeze et al. 2017). This protection from high-velocity bullets would have certainly led to a decrease in the number of thoracic GSW, as a large percentage of bullet threats seen in combat theatres were defeated.

The US forces issued the Improved Outer Tactical Vest (IOTV) in 2007, which saw enhanced SAPI (ESAPI)

Tab. 1: Details of studies identified, thoracic GSW and fatalities

Reference	Quality rating/ Risk of bias	Operational theatre	Period	Population	No of thoracic GSW	% of thoracic wounds that GSW accounted for	% of GSW that thorax accounted for	Number of fatalities from thoracic GSW	% of fatalities from thoracic GSW	Remarks
(Oughterson et al. 1962)	Fair/Unclear	Bougainville	15 Feb–21 Apr 1944	US Army Ground forces	85	40				Accounted for 59.7% of deaths.
(Hopkins 1962)	Good/Low	New Georgia – Burma	Feb–June 1944	1st and 3rd battalion, 5307th Composite unit	63	17		32	50.7	
(Tribby 1962)	Good/Unclear	Italy	1944	1000 American Casualties KIA					32	Thoracic GSW accounted for 9% of all deaths
(Herget et al. 1962)	Fair/Unclear	Korea	15 Nov 1950–5 May 1951	US Army	37	6				
(Brady 2003)	Good/Unclear	Vietnam	July 1967 – June 1969	US Army				51%		
(McNamara et al. 1970)	Fair/Unclear	Vietnam	Sept 1968–Nov 1969	All Nationalities	76	14				
(Boyd 1975)	Good/Low	Belfast	1972–1974	Not detailed	91			43	47.3	
(Moffat 1976)	Good/Low	Northern Ireland	1971–1974	British Serviceman	118	17		48	40.7	
(Mabry et al. 2000)	Fair/Unclear	Somalia	3–4 Oct 1993	United States Army Ranger	2	5				
(Kosashvili et al. 2005)	Fair/Unclear	Israel	Mar 2002–Apr 2002	Israeli defence force	32	44				Kevlar body armour
(Hinsley et al. 2005)	Poor/High	Iraq	21 March and 4 April 2003,	Casualties treated at 202 field hospital	3		10			May include civilians
(Zouris et al. 2006)	Fair/Unclear	Iraq	Mar 23–Apr 30 2003	US marines and sailors		8.5				
(Owens et al. 2008)	Fair/Unclear	Iraq and Afghanistan	Oct 2001–Jan 2005	US service members		19				
(Ramasamy et al. 2009)	Fair/Unclear	Iraq	Jan–Oct 2006	Iraq	3			7		
(Lewis 2006)	Good/Unclear	Iraq	Operation Telic–2006	UK Military						
(Martin 2015) ¹	Poor/Unclear	All theatres	2001–2009	Casualties in JTTR						
(Popivanov et al. 2014)	Poor/High	Afghanistan	2010	Casualties presenting to Bulgarian Military hospital	16		29			May include civilians
(Belmont et al. 2010)	Fair/Unclear	Iraq	Iraq surge phase	US Army Brigade Combat Team,		1.3				
(Poon et al. 2013)	Fair/Unclear	Iraq and Afghanistan	Mar 2003–Mar 2011	UK Military	320	38.7		49	15.3	
(Penn-Barwell et al. 2016)	Good/Unclear	All Active theatres	Jan 2009–31 Dec 2013	UK Military	402		23	269	31	
(Stevenson et al. 2018)	Good/Low	Iraq and Afghanistan	2003–2014	UK military	106	15	22	48	27	
(Schauer et al. 2019)	Poor/Unclear	Iraq and Afghanistan	January 2007 to August 2016.	Casualties presenting to military emergency departments	1087	16.3				May include civilians
(Lesquen et al. 2016)	Poor/High	Afghanistan	2009–2016	Casualties admitted to French NATO combat support hospital	47		53			May include civilians

¹While the article met the criteria for inclusion, it did not discuss the parameters included in this table. GSW, gunshot wound.

plates made from boron carbide that covers critical areas of the torso and provides protection from armour-piercing ammunition, and also features enhanced side ballistic inserts (ESBI) (Brayley 2011).

In 2016 the UK forces were issued VIRTUS scalable tactical vests, which allow the user to scale their protection level depending on the threat. They can be worn in several configurations including no armour, soft armour made of composite granular materials or a full armour system comprising of soft armour and hard ballistic plates (Lewis and Clarke 2018).

4.1.2 Body armour coverage

The original flak jacket fielding in Korea and Vietnam protected the thorax and the abdomen; however, during the 1970s it was recognised that some anatomical structures are more susceptible than others. This led to changes in design to provide the more susceptible anatomic structures extra protection. The soft armour continues to cover the whole thorax and abdomen as it is primarily designed to protect against fragmentation. The INIBA and ECBA plates covered the heart and mediastinum and were developed based on the prevalent threat and favourable condition of medical attention being available within 20 min during the Northern Ireland conflict. The ceramic plates used in the OSPREY system were refined based on the time to medical care being 1–2 h, and in addition to the heart and the mediastinum, also protected the spleen and the liver (Breeze et al. 2016a,b).

ECBA plates have been used in OSPREY and VIRTUS to provide side protection and have been shown to already be optimised to provide side protection despite not being designed for this purpose (Breeze et al. 2021). It has also been recommended that a range of plate sizes should be used to optimise the coverage and effectiveness of body armour (Breeze et al. 2016a,b).

SAPI plates come in five sizes (extra-small to extra-large) designed to optimise fit and comfort for the user whilst providing suitable coverage for a range of body sizes and shapes.

More recently Breeze et al. have defined the essential coverage areas whose structures are likely to result in death within 60 min of significant injury unless damage control surgery (DCS) is received. These areas are defined as '*Heart, Mediastinal great vessels, Superior vena cava, Inferior vena cava, Pulmonary arteries and veins, Aorta, Brachiocephalic artery and veins, Left common carotid artery, Subclavian artery and vein, Iliac arteries and veins, Liver, Spleen, and Intrathoracic trachea*' (Breeze et al. 2020).

4.1.3 Body armour standards

Body armour standards were introduced by the National Institute of Justice in 1972 with other standards such as the NATO Allied Engineering Publication 2920 also being developed over time. The purpose of the standards is to ensure that body armours offer an adequate level of protection against the threats that are tested. This not only ensures that high-velocity bullets are stopped but also that back face deformation of the body armour does not cause excessive blunt force trauma (Carr and Lewis 2014).

Military body armour is procured in accordance with the relevant national authority threats and specifications and therefore this ensures that the most common rounds in combat theatres are defeated and consequentially the number of thoracic GSW and subsequent fatalities are reduced.

4.1.4 Medical response times

During WW2, due to the complexities of evacuation and the sheer volume of casualties it could take between 12 h and 15 h for a casualty to be triaged and provided the necessary care. Based on the experiences of WW2, a Mobile Army Surgical Hospital (MASH) was put in place by the US Army for the Korean War. The MASH provided resuscitative surgical care within 10 miles of the front line and was supported by helicopter ambulances allowing casualties to be treated in 3–12 h of wounding and subsequently the mortality rates of all injuries were reduced. The use of helicopters in the medical evacuation was continued during the Vietnam War and the process improved. The helicopters transported casualties directly to full-service hospitals and reduced the treatment time to 60 min and ensured that treatment was provided within what is considered the golden hour (Manring et al. 2009).

Due to the changes in warfare, MASH hospitals were shown to be unsuitable during the GW1. This led to the formation of Combat Support Hospitals (CSH), with the new CSH first being used in 2003 in Iraq, and more recently the US has used a system that involves five levels of care, ranging from battalion aid stations to stateside trauma centres and a medical response time of 30–90 min (Manring et al. 2009).

Casualty evaluation timelines of UK forces are based on the NATO Allied Joint Publication (AJP) 4–10: Allied Joint Doctrine for Medical Support. The first version published in 2006 stated that battlefield advanced trauma and resuscitation techniques occur within 1 h, DCS

within 2 h and any further surgical procedures within 4 h (1–2–4 principle). An update to medical timelines was published in 2010, and called for first aid within 10 min, skilled medical aid in 1 h and DCS in 2 h. This was formalised in the 2015 update of the AJP 4–10 and became known as the 10–1–2 principle. However, the UK followed 10–1–2(2) +2, where the (2) is time taken to deliver DCS and the +2 is evacuation to deployed hospital care (DHC) for in-theatre surgery. The AJP 4–10 was updated in 2019 to follow these time frames but the +2 refers to further surgical, diagnostic, specialist care etc. being made within 2 h of tactical evacuation after DCS (Scallan et al. 2020).

The Medical Emergency Response Team (MERT) was formed due to the lack of secure road routes in Iraq and Afghanistan and allows medical interventions to be delivered that would normally be restricted to hospital facilities and can also be attributed to the decrease in fatalities (Keene et al. 2017).

4.1.5 Improvement in medical interventions

Improvements in medical techniques are wide-ranging but the key improvements have come in the form of infection treatment, haemostatic resuscitation and thoracic wound treatment.

Penicillin was first discovered in 1928 by Alexander Fleming, but it was not successfully used as a treatment to treat infections until 1942. The first large-scale use of it was not carried out until the D-Day invasions in 1944 and the Korean and Vietnam wars saw penicillin used in conjunction with streptomycin. The treatment of infection would have led to a reduction in the number of fatalities of thoracic GSW, but it was likely that during these conflicts many fatalities occurred before infection became a contributing factor. This is highlighted by broad-spectrum antibiotics not generally being administered in early treatment during the Iraq and Afghanistan conflicts (Manring et al. 2009).

Whole blood transfusions were introduced in 1944 and military blood programmes were established in 1953. Since the 1980s, whole blood has been separated into packed red blood cells (PRBC), fresh frozen plasma (FFP), platelets and cryoprecipitate. This allows specific components of blood to be administered without the risks of using whole blood and a ratio of 1:1:1 (platelets: FFP: PRBC) has been shown to improve mortality. Once bleeding is controlled, a more tailored approach is used to improve blood volume and pressure. Coagulopathy is assessed and any intervention needed is delivered. Tranexamic acid (TXA)

is administered within 3 h and has also been shown to significantly reduce mortality in trauma bleeding casualties (Keene, et al. 2017).

Thoracic wound treatment has evolved from needle aspiration in WW2, to thoracentesis during the Korean and Vietnam wars, to tube thoracotomy in the 1980s, to more modern techniques including using vented chest seals, needle thoracentesis and simple thoracostomy, which has been shown to reduce the risk of pneumothorax (Kotora et al. 2013, Littlejohn 2017) and would have subsequently reduced the number of fatalities.

4.1.6 Study limitations

This study has several limitations. Firstly, the reporting of patients injured varies; for example, Schauer's study (Schauer et al. 2019) showed a significant increase in the number of casualties presenting at military emergency departments with thoracic GSWs in Iraq and Afghanistan. Hinsley's study (Hinsley et al. 2005) also showed an increase in the number of casualties presenting to the field hospital in the first 2 weeks of Operation Telic; however, both of these studies may have included unprotected civilian casualties. In contrast, Kosashvili's study (Kosashvili et al. 2005) also showed an increase in the frequency of casualties suffering from thoracic GSWs; however, it should be noted that the majority of casualties were only wearing Kevlar body armour, which offers very little protection against high-velocity bullets. Secondly, the format of the data in the sources is varied, ranging from the percentage of all injuries, percentage of thoracic injuries and percentage of GSWs. While some sources provided detailed information, many sources did not. Thirdly, the included studies rarely detailed if body armour was being worn and if so the type of armour, and therefore, it cannot be determined if the development of body armour alone has directly reduced the mortality from these injuries. Fourthly, it is unknown if the studies include fatalities that occurred before treatment could be received, or if injuries that did not require hospital treatment are captured. Lastly, it is difficult to make comparisons between the combat environments because of the way in which information is presented and many studies having an unclear bias; therefore, only broad general observations can be made.

However, despite these limitations, it is clear that GSWs to the thorax remain a credible risk. This review confirms that advancements in body armour have not eliminated the threat of thoracic GSW, which still account for approximately 15% of all thoracic injuries in the

most recent combat theatres (Stevenson, Carr et al. 2018, Schauer, Naylor et al. 2019). Thus, roles 1 and 2 medical personnel should be aware of the frequency and severity of thoracic gunshot injuries and should be prepared to treat these life-threatening injuries.

4.1.7 Future work

Future systematic review work should include the inclusion of injuries caused by fragmentation due to the change in the nature of warfare and IEDs being a prevalent threat. It should also include sensitivity analysis to determine the effects of including studies with an unclear risk of bias on the overall analysis and observations made.

With the developments of new materials and armour that can protect against armour-piercing ammunition, further research should be carried out to look at the trade-offs between protection and mobility and how improved operability can subsequently improve survivability.

With the changing face of combat, the traumatic injuries incurred are likely to change; thus, future studies should focus on these changes to optimise the prevention and treatment of casualties.

5 Conclusion

This systematic review identifies that thoracic GSW continues to present a risk to military personnel despite the improvement of body armour, evacuation times, medical techniques and the changes in warfare. Therefore, medical personnel should be prepared to treat these life-threatening injuries and further research should be carried out to reduce thoracic GSW, if possible.

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Competing interest

The authors declare that they have no conflict of interest.

Ethical approval and consent to participate

Ethical approval was not needed for this systematic review.

Consent for publication

Not applicable.

Availability of data and materials

Supplied as additional files or within the text.

Code availability

Not applicable.

Authors' contribution

Amy Pullen and David Kieser developed the criteria. Amy Pullen carried out the review. David Kieser and Gary Hooper supervised the work, verified the analytical methods and reviewed the results. The first draft of the manuscript was written by Amy Pullen and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Appendix

Tab. A1: Criteria for the modified Newcastle-Ottawa Scale regarding star allocation to assess quality of studies

Criteria	Acceptable (star awarded)	Unacceptable (star not awarded)
Representativeness of exposed cohort (*)	Population based	Hospital based Civilians included
Ascertainment of exposure (*)	Trauma records	Anecdotal evidence
Comparability (**)	** awarded for both number of casualties and number of fatalities comparable * awarded for only one metric comparable	No metrics comparable
Assessment of outcome(*)	Trauma records	No outcome data

Tab. A2: Quality assessment of studies using a modified Newcastle Ottawa Scale for assessing studies in the systematic review of military thoracic gunshot injuries

Study ID	Selection		Comparability	Outcome	Total score (5*)
	Representativeness of exposed cohort (*)	Ascertainment of exposure (*)	(**)	Assessment of outcome(*)	
(Herget et al. 1962)	*	*	*		3
(Hopkins 1962)	*	*	**	*	5
(Oughterson et al. 1962)	*	*	*		3
(Tribby 1962)	*	*	**	*	5
(McNamara et al. 1970)	*	*	*		3
(Boyd 1975)	*	*	**	*	5
(Moffat 1976)	*	*	**	*	5
(Mabry et al. 2000)	*	*	*		3
(Brady 2003)	*	*	*	*	4
(Kosashvili et al. 2005)	*	*	*		3
(Hinsley et al. 2005)		*	*		2
(Lewis 2006)	*	*	**	*	5
(Zouris et al. 2006)	*	*	*		3
(Owens et al. 2008)	*	*	*		3
(Ramasamy et al. 2009)	*	*	*		3
(Belmont Jr et al. 2010)	*	*	*		3
(Poon et al. 2013)	*	*	*		3
(Popivanov et al. 2014)		*	*		2
(Martin 2015)	*	*			2
(Lesquen et al. 2016)		*	*		2
(Penn-Barwell et al. 2016)	*	*	**	*	5
(Stevenson et al. 2018)	*	*	**	*	5
(Schauer et al. 2019)		*	*		2

Total score: 1-2 poor quality, 3= fair quality, 4-5= Good quality

Tab. A3: Risk of bias assessment using a modified Cochrane Tool

Study ID	Allocation concealment (Selection bias)	Assessment of exposure (Performance bias)	Outcome of interest present at beginning (detection bias)	Incomplete data (attrition bias)	Selective reporting (reporting bias)	Total score*
(Herget et al. 1962)	+	+	+	?	?	3
(Hopkins 1962)	+	+	+	+	?	4
(Oughterson et al. 1962)	+	+	+	?	?	3
(Tribby 1962)	+	+	+	?	?	3
(McNamara et al. 1970)	+	+	+	?	?	3
(Boyd 1975)	+	+	+	+	?	4
(Moffat 1976)	+	+	+	+	?	4
(Mabry et al. 2000)	+	+	+	?	?	3
(Brady 2003)	+	+	+	?	?	3
(Kosashvili et al. 2005)	+	+	+	?	?	3
(Hinsley et al. 2005)	-	+	+	?	?	2
(Lewis 2006)	+	+	+	?	?	3
(Zouris et al. 2006)	+	+	+	?	?	3
(Owens et al. 2008)	+	+	+	?	?	3
(Ramasamy et al. 2009)	+	+	+	?	?	3
(Belmont Jr et al. 2010)	+	+	+	?	?	3
(Poon et al. 2013)	+	+	+	?	?	3
(Popivanov et al. 2014)	-	+	+	?	?	2
(Martin 2015)	+	+	+	?	?	3
(Lesquen et al. 2016)	-	+	+	?	?	2
(Penn-Barwell et al. 2016)	-	+	+	+	?	3
(Stevenson et al. 2018)	+	+	+	+	?	4
(Schauer et al. 2019)	+	+	+	?	?	3

■ = Low risk of bias, ? = Unclear risk of bias, ■ = High risk of bias.

*Total score = Points awarded based on number of low risks of bias. 1-2= High risk of bias, 3=unclear risk of bias 4-5=low risk of bias