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EVIDENCE REVIEW

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A scoping review on intraoperative and postoperative surgical castration complications in domesticated equids

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Abstract

Background: Castration is the most common surgical procedure in domesticated equids; surgical techniques used and perioperative management vary considerably.

Objectives: To identify and chart the current evidence on perioperative complications associated with different methods of surgical castration in domesticated equids.

Study design: Joanna Briggs Institute systematic scoping review.

Method: CAB Abstracts, Medline and Embase databases were searched using terms related to equine castration complications. Two authors independently and blindly screened publications against eligibility criteria. Data on study methods, perioperative management, surgical techniques, and perioperative complications were extracted. Surgical techniques were grouped into categories depending on technique; open, closed or half-closed, and whether the parietal tunic was open or closed at the end of surgery.

Results: The search identified 1871 publications; 71 studies met the final inclusion criteria. The data reported 76 734 castrations, most of which were open or closed, with the vaginal tunic remaining open at the end of surgery. Twenty-five studies reported information regarding surgical techniques and perioperative management, allowing detailed charting and comparisons, of which analgesia and antimicrobial usage varied notably. Eighteen different complications were reported, with swelling or oedema being the most common. Evisceration was most commonly reported in draught breeds and Standardbreds, and the risk appeared low if the parietal tunic was closed at the end of surgery.

Main limitations: Grey literature and studies not available in English were not included. Existing studies varied greatly in perioperative management, surgical techniques and reporting of outcomes, making evidence consolidation problematic.

Conclusion: A lack of consensus regarding complication definitions creates uncertainty and discrepancies between complication rates associated with different surgical techniques and perioperative management. The implementation of standardised systems for describing surgical techniques and complications is recommended for

future studies. A number of studies did not follow current recommendations for perioperative analgesia and use of antimicrobials.

KEYWORDS
castration, emasculation, general anaesthesia, horse, stallion, swelling

1 | INTRODUCTION

Castration of domesticated equids is the most common surgical procedure in equine veterinary practice performed worldwide. Despite this or potentially because of this, there is widespread variation in the perioperative management and surgical techniques used. There are numerous approaches to the surgery and the quality of evidence regarding various castration methods is limited. Most complications reported for this routine procedure are mild[1] and serious complications are infrequent but can be fatal.[2–6]

There are three definitions currently recognised for the surgical technique of castration: open, closed and half-closed.[7] The definitions are dependent on whether the parietal tunic is incised before removal of the testicle and whether a portion of the parietal tunic is removed. The parietal tunic and the visceral tunic together make up the vaginal tunic. With any of these techniques, the parietal tunic can be closed or left open at the end of surgery. There is a lack of consistency when defining surgical techniques.[8] Considerable overlap is found relating to the terms 'open' and 'closed' when discussing surgical technique, whether the parietal tunic remains open or is closed at the end of surgery and whether skin closure has been performed. Reported complication rates range from 2.1% to 60%.[2,3,5,6,9–13]

A scoping review is a useful initial step to identify existing research, pinpoint gaps in the current research, clarify fundamental definitions and map out the literature, irrespective of quality.[14–16] Currently there are narrative reviews on complications of castration but no published systematic reviews. Scoping reviews are particularly valuable when a body of literature exhibits a vast, complex nature not amenable to a more precise systematic review, which is the case for this topic.[17] A systematic review would be more appropriate for specific questions on a topic with less variability within the available literature. This scoping review aims to identify the literature available on the outcomes of castration and evaluate whether associations can be made between complications and varied management and techniques. These reviews provide researchers with a comprehensive understanding of the existing evidence, influencing not just future research but also evidence-based guidelines and policies to assist veterinary surgeons.[18]

The objectives include (1) performing a systematic search of the databases to establish the current peer-reviewed literature on intraoperative and postoperative complications following surgical castration; (2) obtaining relevant data on castration complications to map and chart the findings, specifically analysing associations with the castration technique, use of antimicrobials and analgesia provided; (3) evaluating whether castration technique has any reported influence over the type or rate of complications identified; (4) identifying any knowledge gaps to construct recommendations for future studies.

2 | MATERIALS AND METHODS

2.1 | Protocol and registration

This scoping review adheres to the Joanna Briggs Institute systematic scoping review protocol guideline,[14] and follows the preferred Reporting Items for systematic reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) framework.[18] The protocol for this review was registered on Open Science Framework (http://osf.io/79yxz/).

2.2 | Eligibility criteria

A paper was included in the study if the criteria were met, the full text of the paper was available in English and could be accessed from any of the Nottingham University libraries, e-libraries or free online Open Access. Studies that did not report any outcome data during or after castration, were not included. The full eligibility criteria are displayed in Table 1.

An Equid was required to have two healthy testicles descended into the scrotum before undergoing castration to be eligible for inclusion. The testicles had to be free of neoplasia, orchitis, infection, trauma or testicular torsion to be considered healthy.

For this scoping review, the following definitions were used: (1) surgical castration = the removal of two testicles; (2) surgical complication = as defined in each individual manuscript; (3) intraoperative = the period during a surgical procedure; (4) postoperative = the period after a surgical procedure has finished. There is no time limit on this period. If the complication has transpired from the surgery, it will be considered as a postoperative complication.

2.3 | Information sources

Three databases were used for the searches: CAB Abstracts (1973–present), Embase (1974–present) and Medline In-Process & Non-Indexed Citations and Ovid MEDLINE (1946–present).

Medline and CAB Abstracts are reported as the two key veterinary literature databases.[17] A previous scoping review found some

TABLE 1 Inclusion and exclusion criteria for a scoping review of castration complications in domesticated equids.

Criteria	Inclusion	Exclusion
Population	All types of male domesticated equids.	Non-equids and hermaphrodites.
Exposures	Entire males (colts and stallions) presented for castration with two healthy testicles descended into the scrotum.	Cryptorchids Neoplasia, orchitis, infection, trauma, testicular torsion
Intervention	Surgical castration (confirmed by the removal of two testicles) using procedures that include open, closed, half-closed or modified versions of these techniques, understanding sedation or general anaesthesia.	Non-surgical castration.
Outcome	Papers including intraoperative and/or postoperative complications.	Papers where intraoperative and/or postoperative complications are not reported. Anaesthetic morbidity and mortality.
Language	English or papers with available translation.	Papers with no English translation available.
Study design	Case series, randomised controlled trials, cohort, case control, cross-sectional studies and individual case reports.	Textbook chapters Review articles
Publication type	Peer reviewed journals, conference abstracts.	Non-peer reviewed journals. Unable to obtain full paper.

specific equine journals are not covered by CAB Abstracts or Medline, therefore Embase was included in the search databases.[19] The search was performed on 17 January 2024.

2.4 | Search strategy

The PICO search strategy was reviewed by a librarian from the University of Nottingham and all authors (Data S1). The results of the search were downloaded onto EndNote 20. Any duplicates were removed by the primary researcher (E) (Figure 1). Two authors (E.R. and S.F.) reviewed the titles and abstracts independently, one of which (S.F.) is an accredited JBI reviewer. Any titles or abstracts that were unclear, ambiguous or where the two authors disagreed were retained until the next stage. The primary author independently assessed the full text of the final included papers, and any ambiguous studies were discussed by two authors (E.R. and S.F.), both authors agreed on the final included studies. The reference lists of all retrieved studies were hand-searched for additional relevant studies.

2.5 | Data charting process

Final papers were analysed, and the relevant data were extracted by the primary author using a data extraction template (Table S1). Studies that contained sufficient detail regarding surgical technique, outcomes and perioperative management for this to be extracted and charted were analysed separately (Tables 2, 3, and S2). Data from individual case reports and studies that lacked information about perioperative management and surgical technique were reviewed and charted separately (Tables S3 and S4).

Data were analysed according to the surgical technique of open, closed or half-closed and whether the parietal tunic was left open or closed at the end of the surgery, resulting in six different categories (Table 4). There is variation in the current literature and studies of how these techniques are described, and therefore, the following definitions were used for this study: the open technique involves incising the parietal tunic to exteriorise the testicle, cutting the ligament of the tail of the epididymis, and transecting the spermatic cord, ultimately the parietal tunic remains; the closed technique does not involve opening the parietal tunic to expose the testicle, but instead, removal of the testicle inside the parietal tunic and a portion of the parietal tunic is removed; the half-closed technique involves an opening into the parietal tunic to expose the testicle and inspect the content, although the parietal tunic is removed along with the testis and a portion of the spermatic cord.[7] If sutures are placed to prevent free communication through the parietal tunic, the tunic itself would be considered closed at the end of surgery. The parietal tunic can be closed or left open with any of the three surgical techniques of open, closed or half-closed, which is where the majority of confusion around these definitions transpires. Closure of the parietal tunic can be achieved by ligating the spermatic cord and including the parietal tunic, or by suturing the parietal tunic alone.

All reported surgical techniques corresponded to one of the six surgical groups, despite descriptions of modified versions. A method of opening the parietal tunic to remove the testicle and cord, before suturing closed the tunic was classified as a half-closed technique in one study,[20] and modified open in another.[9] While there are similarities between techniques, the parietal tunic has remained in both cases, and therefore, these techniques were categorised as open in this review and grouped in Category 2. A further study reported a modified half-closed technique by transecting the cord without the parietal tunic and then replacing the stump into the parietal tunic and performing another emasculation to remove the tunic.[27] This technique has been categorised as half-closed and grouped in Category 5.

No further analysis was conducted to evaluate the risk of bias or methodological quality, in line with the scoping review protocol.[15,18]

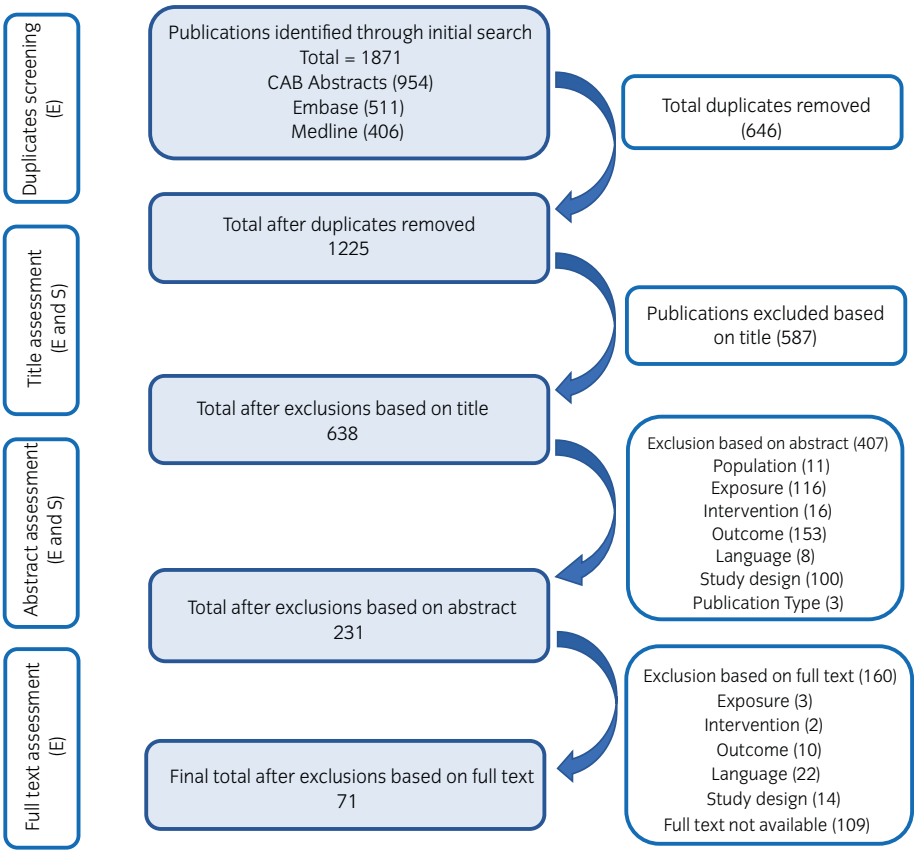


FIGURE 1 A PRISMA flow diagram to show the selection process used to identify publications for a scoping review on castration complications of domesticated equids. The initials represent authors (E.R. and S.F.).

3 | RESULTS

3.1 | Selection of sources of evidence

A total of 1871 studies were identified on the initial database searches. Following duplicate removal, 1225 titles were reviewed against inclusion and exclusion criteria, 638 abstracts were reviewed and 71 papers met the final inclusion criteria and were reviewed (Figure 1).

Twenty-five of the 71 papers included adequate information regarding the surgical procedure and reported outcomes for full analysis (Table S2). Fourteen papers were individual case reports (Table S3), and 32 papers did not include any information regarding the original castration procedure or lacked reporting of outcomes. This included anaesthesia-related studies, which predominantly evaluated pain during the procedure and postoperatively (Table S4).

3.2 | Study characteristics

The 71 included papers were published between 1972 and 2023, with 58 published after 2000 and 18 published from 2020 onwards. Two of the studies were conducted across multiple countries and the remaining 69 were from single countries: USA ($n = 18$), Brazil ($n = 9$), UK ($n = 8$), Canada ($n = 5$), Australia, Italy, Germany and Switzerland ($n = 4$), Denmark and Egypt ($n = 3$), South Africa ($n = 2$) and Spain, Belgium, Sweden, Iraq and Hong Kong ($n = 1$). There were a range of study designs, the most common being randomised controlled trials (19/71), retrospective case series (18/71) and individual case reports (14/71).

The only reported intraoperative complication was haemorrhage. There were no reports of intraoperative penile damage but one documented case of postoperative penile paralysis,[35] and a case report of a chronic penile retroversion through a scrotal incision.[36] Eighteen types of postoperative complications were reported within the studies from a total of 76 734 cases (Tables S2–S4). The most common reported complication was swelling or oedema, followed by pyrexia and then by surgical site infection, septic funiculitis, evisceration, seroma, and surgical site discharge. The remaining complications were less frequently reported: septic peritonitis, hydrocele, haematoma, subcutaneous tissue prolapse, adhesions, lameness or stiffness, tetanus, penile paralysis and penile retroversion through a scrotal incision (Tables S2–S4).

The classification systems implemented for the degree of oedema or swelling, haemorrhage and pyrexia varied remarkably between studies. Mild swelling or oedema was either not recorded, or was discussed but not included in the overall complication rates in most studies.[9,11,12,30] Some studies also excluded moderate cases of swelling.[28] Two large studies included mild cases of swelling in their complication rates,[13,35] resulting in much higher complication rates of up to 60%.

Several classification systems were implemented to categorise the severity of swellings.[9,11] One study classified mild scrotal swelling

TABLE 2 A table to show the surgical castration techniques performed within individual studies and corresponding complications in a scoping review of castration complications in domesticated equids.

Author and year	Group	Surgical technique	Approach	Spermatic cord ligation	Emasculators	Parietal tunic sutured	Skin sutured	Swelling/ oedema	Haemorrhage	Omentral evisceration	Intestinal evisceration	Subcutaneous tissue prolapse	Pyrexia	Surgical site infection	Colic	Incisional drainage	Septic Funiculitis	Septic peritonitis	Lameness/ stiffness	Seroma	Haematoma
Alonso et al., 2021[20]	2	Open	Scrotal	T.CGT																	
	1	Open	Scrotal	T.CGT																	
Barber et al., 1985[21]	3	Closed	Scrotal Ablation		1–3 min			1													
Barreto et al., 2022[22]	2	Open	Para-scrotal	T.PGA	5 min	PGA	PGA														
	2	Open	Scrotal Ablation	T.PGA	5 min	PGA															
Bergstorm et al., 2020[23]	3	Closed	Scrotal Ablation					3				4				19					
Birrell et al., 2021[24]	1	Open	Scrotal											1	1						
Busk et al., 2010[25]	5	Half-closed	Scrotal		5 min									3[a]			1[a]				
Carmalt et al., 2008[2]	4	Closed	Scrotal	PGN				5	3	1						1					
Crosa et al., 2018[9]	2	Open	Scrotal	AL		PGC + AL	PGC	2	2[b]				2								
Eesa 2005[26]	4	Closed	Inguinal	T																	
Giusto et al., 2016[27]	5	Half-closed	–																		
Gobbi et al., 2020[28]	1	Open	Scrotal	P910	–			5											4		
Gracia-calvo et al., 2012[29]	1	Open	Inguinal		Ligasure		–						2	1							
Haucke et al., 2017[30]	4	Closed	Scrotal	PGA	4 min			7				10	10			8					
Hinton et al., 2019[3]	3	Closed	Scrotal		Henderson			7		2	1		1	1						15	
Hutchins et al., 1972[4]	1	Open	Scrotal								11										
Ibrahim et al., 2021[31]	2	Osubcapo	Scrotal			P910	P910	4													
	1	Open	Scrotal	P910	2 min			8	1					1							
Jacobsen et al., 2005[32]	5	Half-closed	Scrotal	only 3 × lig				13					2			6					
Koenig et al., 2019[6]	4	Closed	Scrotal	T, P910	2–3 min				1					2			1				
	3	Closed	Scrotal		2–3 min					1							2				
	4	Closed	Scrotal	T	2–3 min					1				2			4				
Kummer et al., 2009[11]	2	Open	Inguinal	T + 1 normal				148	1				52		21					4	4
Mason et al., 2005[12]	1	Open	Scrotal		4 min				2					25							
	2	Open	Scrotal	CGUT		CGUT	P910		1					2							
Petrizzi et al., 2006[33]	2	Open	Inguinal		Ligasure	G631	G631	4							1						
	2	Open	Inguinal	T, PS		G631	G631	1													

(Continues)

TABLE 2 (Continued)

Author and year	Group	Surgical technique	Approach	Spermatic cord ligation	Emasculators	Parietal tunic sutured	Skin sutured	Swelling/oedema	Haemorrhage	Omental evisceration	Intestinal evisceration	Subcutaneous tissue prolapse	Pyrexia	Surgical site infection	Colic	Incisional drainage	Septic Funiculitis	Septic peritonitis	Lameness/stiffness	Seroma	Haematoma
Racine et al., 2019[5]	3	Closed	Scrotal		Henderson			29	12	2				27			1				
Rosanowski et al., 2018[13]	1	Open	Scrotal					105	23				32		5	21	56		13	37	
Schumacher et al., 1988[34]	1	Open	3	2 × CGUT									11								
Shoemaker et al., 2004[10]	1	Open	Scrotal	[c]	min 90 s					6	8										
	3	Closed	Scrotal	[c]	min 90 s					10	18										

Note: This table reports the surgical technique utilised in each study and includes information on the approach, whether the spermatic cord was ligated, if emasculators were used, parietal tunic closure and skin closure. The number of complications reported in each study are also presented. There is great variation between individual studies and their reported complications.
Abbreviations: AL, absorbable lactomer; CGT, catgut; G631, glycomer 631; green, yes; P910, polygalactin 910; PDS, polydiaxanone; PGA, polyglycolic acid; PGC, poliglecaprone 25; PGN, polyglyconate; PS, polysorb; red, no; T, transfixed.
[a]Two cases of surgical site infection and one septic funiculitis excluded in this study due to a high preoperative SAA.
[b]Intraoperative complication.
[c]26 Cases had ligatures and the rest did not.

as less than 5 cm or moderate as more than 5 cm, and severe as more than 10 cm.[11] A similar system employed pictures to categorise swelling into five grades, mild, mild–moderate, moderate, moderate to severe and severe.[30] A further five-point grading system with images was utilised, although no labelling of mild, moderate or severe took place.[37] Other studies simply labelled swelling more than 3 cm,[38] swelling larger than fist size[33] or swelling that required veterinary attention, as a complication.[6]

Some bleeding from the surgical site can be considered normal, with most studies only classifying haemorrhage as a complication when it is severe or requires veterinary intervention.[6] Severe haemorrhage has been classified as a stream of blood for more than 15 min that prompted measures to stop the bleeding.[5] Time frames of 15–20 min,[39] and 30 min have also been used.[12] Moderate haemorrhage has been reported as a complication, defined as dripping of blood that stopped spontaneously within 15 min, prompting closer observation but not requiring additional veterinary intervention.[5]

Pyrexia is not a specific complication of castration, but a common postoperative finding when temperatures are monitored. In this review, some studies categorised pyrexia as a complication if the temperature was more than 39.0°C for at least 24 h.[30] Another study considered pyrexia of more than 38.4°C within the first 48 h as normal and pyrexia of more than 39.4°C after this time frame as a complication.[11] These cases resolved spontaneously without treatment but created a complication rate of 20.2%. Most studies did not monitor temperature or did not consider pyrexia as a complication.[9]

3.3 | Results of individual sources of evidence

There were 25 of 71 studies containing comprehensive information regarding the surgical castration procedure and reported outcomes (Table S2). The surgical techniques and complications observed in each of these studies are reported in Table 2 and the perioperative management in Table 3. All individual cases were grouped according to the surgical technique used for castration and whether the parietal tunic was open or closed at the end of surgery (as defined in Table 4).

There was only one case of omental or intestinal evisceration in groups where the parietal tunic was closed at the end of surgery (Figure 2). There were 25 of 1065 (2.35%) cases of evisceration in Group 1 (open technique with an open parietal tunic at the end of surgery) and 34 of 959 (3.55%) evisceration cases in Group 3 (closed technique with an open parietal tunic at the end of surgery) (Figure 2). One case of intestinal evisceration that had a ligature placed to close the parietal tunic was excluded from analysis due to the presence of an inguinal hernia at the time of castration.[10] Standardbreds and draught breeds were overrepresented within the evisceration cases.

Emasculators were used in 17 of 25 studies, held in place between 1 and 5 min (Table 2). No emasculators were used in five studies, the Henderson device was used for two studies, the Ligasure Atlas (LSA) device for one study and one did not report on the use of emasculators. Of 25 studies, 18 studies used a scrotal approach and 9 studies closed the skin incisions. Of 25 studies, 12 studies applied at

TABLE 3 A table to show the antimicrobial and analgesic perioperative protocols in a scoping review of castration complications of domesticated equids.

Author and year	Local anaesthetic	Analgesia				Antimicrobials			
		Pre	Intra	Post	Duration	Pre	Intra	Post	Duration
Alonso et al., 2021[20]	✓	X	X	✓ Flunixin	3 days SID	X	X	✓ IM Penicillin	q48hrs 6 days
	✓	X	X	✓ Flunixin	3 days SID	X	X	✓ IM Penicillin	q48hrs 6 days
Barber et al., 1985[21]	–	–	–	–		–	–	–	–
Barreto et al., 2022[22]	✓	X	X	✓ Sodium dipyrone	5 days SID	X	X	✓ IM Pen + Strep	q48hrs 6 days
	✓	X	X	✓ Sodium dipyrone	6 days SID	X	X	✓ IM Pen + Strep	q48hrs 6 days
Bergstorm et al., 2020[23]	✓	X	✓ Flunixin	X		X	✓ IM Ceftiofur	X	
	✓	X	✓ Flunixin	X		X	✓ IM Penicillin	X	
Birrell et al., 2021[24]	–	X	X	X		X	X	X	
Busk et al., 2010[25]	✓	✓ Flunixin	X	✓ Flunixin	2 days SID	X	X	X	
	✓	✓ Flunixin	X	✓ Flunixin	2 days SID	✓ IM Penicillin	X	✓ IM Penicilin	2 days SID
Carmalt et al., 2008[2]	–	–	–	–		✓ IM Penicillin	X	–	–
Crosa et al., 2018[9]	✓	✓ Flunixin	X	✓ Flunixn/PBZ	3 days BID	✓ IM Pen + IV Gent	X	✓ Varied	
Eesa et al., 2005[26]	X	–	–	–		✓ IM Pen + Strep	X	✓ IM Pen + Strep	3 days
Giusto et al., 2016[27]	–	–	–	–		–	–	–	–
Gobbi et al., 2020[28]	✓	X	X	Flunixin/firocoxib/ meloxicam	5 days SID	X	X	✓ IM Pen + Strep	3 days SID
Gracia-calvo et al., 2012[29]	–	✓ Flunixin/PBZ	X	✓ Flunixin/PBZ	3 days BID	✓ IM Pen + Gent	X	X	3 days
Haucke et al., 2017[30]	X	✓ Flunixin	X	✓ Flunixin	2 days SID	✓ IV Penicillin	X	X	
	X	✓ Flunixin	X	✓ Flunixin	2 days SID	✓ IV Penicillin	X	✓ IV Penicillin	2 days SID
Hinton et al., 2019[3]	✓	✓ Flunixin/PBZ	X	X		X	X	–	
Hutchins et al., 1972[4]	✓	–	–	–		✓		–	
Ibrahim et al., 2021[31]	✓	✓ Flunixin	X	✓ Flunixin	5 days BID	✓ IM Amox + Gent	X	✓ IM AmoxGent	5 days SID
	✓	✓ Flunixin	X	✓ Flunixin	5 days BID	✓ IM Amox + Gent	X	✓ IM AmoxGent	5 days SID
Jacobsen et al., 2005[32]	✓	X	X	✓ Flunixin	3 days BID	✓ Ampicillin	X	–	
Koenig et al., 2019[6]	✓	✓PBZ	X	✓ PBZ	3–5 days	✓ IM Penicillin	X	–	
	✓	✓ PBZ (1 × Fx)	X	✓ PBZ	3–5 days	✓ IM Pen/IV TMP/IV Gent or X	X	–	
	✓	✓ Flunixin/PBZ	X	✓ PBZ	3–5 days	✓ IV Pen, 7 (Pen + Gent)	X	–	
Kummer et al., 2009[11]		✓ Flunixin	✓ Morphine	✓ PBZ	3 days BID	✓ IV Pen + Gent	X	✓ IV Penicillin	1 dose postop
Mason et al., 2005[12]	✓	✓ PBZ	X	✓ PBZ	6 days BID	✓ IM Penicillin	X	✓ PO Trimediazine	6 days BID
	X	X	X	✓ PBZ	5 days BID	✓ IM Penicillin	X	✓ PO Trimediazine	6 days BID

(Continues)

TABLE 3 (Continued)

Author and year	Local anaesthetic	Analgesia Pre	Analgesia Intra	Analgesia Post	Analgesia Duration	Antimicrobials Pre	Antimicrobials Intra	Antimicrobials Post	Antimicrobials Duration
Petrizzi et al., 2006[33]	X	✓ Flunixin	X	✓ PBZ	2 days BID	✓ IV Pen + Gent	X	✓ IV Penicillin	1 dose postop
	X	✓ Flunixin	X	✓ PBZ	2 days BID	✓ IV Pen + Gent	X	✓ IV Penicillin	1 dosepostop
Racine et al., 2019[5]	✓	X	X	✓ Meloxicam	3 days	✓ IV Pen + Gent	X	Surgeon preferance	
Rosanowski et al., 2018[13]	✓	–	–	✓ PBZ or none	< or >7 days	–	–	Varied	≤ or ≥7 days or none
Schumacher et al., 1988[34]	–	X	X	X		X	X	X	
Shoemaker et al., 2004[10]	X	X	X	–		✓ IM Pen + IV Gent	X	–	
	X	X	X	–		✓ IM Pen + IV Gent	X	–	

Note: This table reports on the perioperative management of surgical castration cases, including whether local anaesthetic was used, whether analgesia and antimicrobials were used and if so, what the protocol was. This table shows that no two studies utilised the same perioperative management protocol and within individual studies the management varied, making comparisons difficult.

Abbreviations: ✓, yes; –, unknown or not reported in the study; BID, twice daily; Gent, gentamicin; PBZ, phenylbutazone; Pen, penicillin; SID, once daily; X, no.

least one ligature around the spermatic cord with over half of these utilising a transfixing ligature. There was no consistency in suture material and size between studies.

Local anaesthesia, analgesia and antimicrobials were utilised in most studies. The perioperative management, however, varied tremendously (Table 3). There were 10 of 25 papers administering no preoperative analgesia and four gave no postoperative analgesia. Two of these papers, from 1988 and 2020, stated they did not provide any perioperative analgesia. Flunixin meglumine or phenylbutazone were equally found to be the choice of analgesia postoperatively. The duration of administration varied from 2 days to more than 7 days; five studies administered non-steroidal anti-inflammatory drugs (NSAIDs) once daily, seven administered twice daily and the rest did not state dosing intervals. One study used sodium dipyrone as their sole analgesia.[22]

No preoperative or intraoperative antimicrobials were administered in 6 of 25 studies, of which two also gave no postoperative antimicrobials. A further three papers did not state whether any were used. All the studies utilising preoperative antimicrobials administered penicillin, apart from two studies that used amoxicillin and gentamicin or ampicillin. Seven studies reported the use of gentamicin and penicillin, and all of these had just one preoperative dose. Three studies administered antimicrobials 1 h preoperatively, one study administered antimicrobials 2 h preoperatively and one study administered ceftiofur or penicillin once the horse was anaesthetised. A lower infection rate with the use of antimicrobials was reported in one survey[35]; however, dosages and duration of administration were not reported and many other confounding factors were present. In contrast, another study comparing a group that received antimicrobials with a group that did not receive any, found just one case of surgical site infection from the antimicrobial group.[25]

There were 14 of 71 individual case reports (Table S3), including a case of large colon evisceration postoperatively.[40] There was a lack of information regarding surgical procedures or postoperative outcomes in 32 of 71 studies and these could not be adequately analysed (Table S4).

4 | DISCUSSION

4.1 | Summary of evidence

This scoping review has revealed a considerable disparity between studies and even between surgical cases within individual studies. Direct comparisons and definitive conclusions are difficult to make due to the numerous changing variables. It is clear that the open, closed and half-closed techniques cannot be compared effectively without knowing the status of the parietal tunic at the end of surgery. What some authors will classify as a complication, some consider a 'normal' postoperative finding. This inconsistency is particularly evident when considering swelling, haemorrhage, pyrexia and pain, and this contributes to the disparity in reported complication rates, ranging from 2.1% to 60%.[2,3,5,6,9–13]

TABLE 4 A table to classify the surgical technique performed for castration of domesticated equids.

Group	Surgical technique	Parietal tunic at the end of surgery
1	**Open** The parietal tunic is incised to exterorise the testicle, cutting the ligament of the tail of the epididymis, and transecting the spermatic cord, ultimately the parietal tunic remains.	**Open** (no closure of the parietal tunic performed)
2		**Closed** (sutures used to close parietal tunic preventing free communication through the tunic)
3	**Closed** There is no opening of the parietal tunic to expose the testicle but instead, removal of the testicle inside the parietal tunic and a portion off the parietal tunic is removed.	**Open** (no closure of the parietal tunic performed)
4		**Closed** (sutures used to close parietal tunic preventing free communication through the tunic)
5	**Half-closed** The parietal tunic is opened to expose the testicle and inspect the content, although the parietal tunic is removed alongside the testes and a portion of spermatic cord	**Open** (no closure of the parietal tunic performed)
6		**Closed** (sutures used to close parietal tunic preventing free communication through the tunic)

In the human literature, postoperative pyrexia starting more than 48 h following surgery was more likely to be associated with infection, and pyrexia within this time frame was not.[41] In horses undergoing colic surgery, a similar trend was found, concluding that pyrexia starting more than 48 h after surgery resulted in higher infection rates.[42] Most studies did not monitor pyrexia or consider it a complication; however, studies that did record temperatures varied in their definitions and the acceptable time frame for its occurrence.

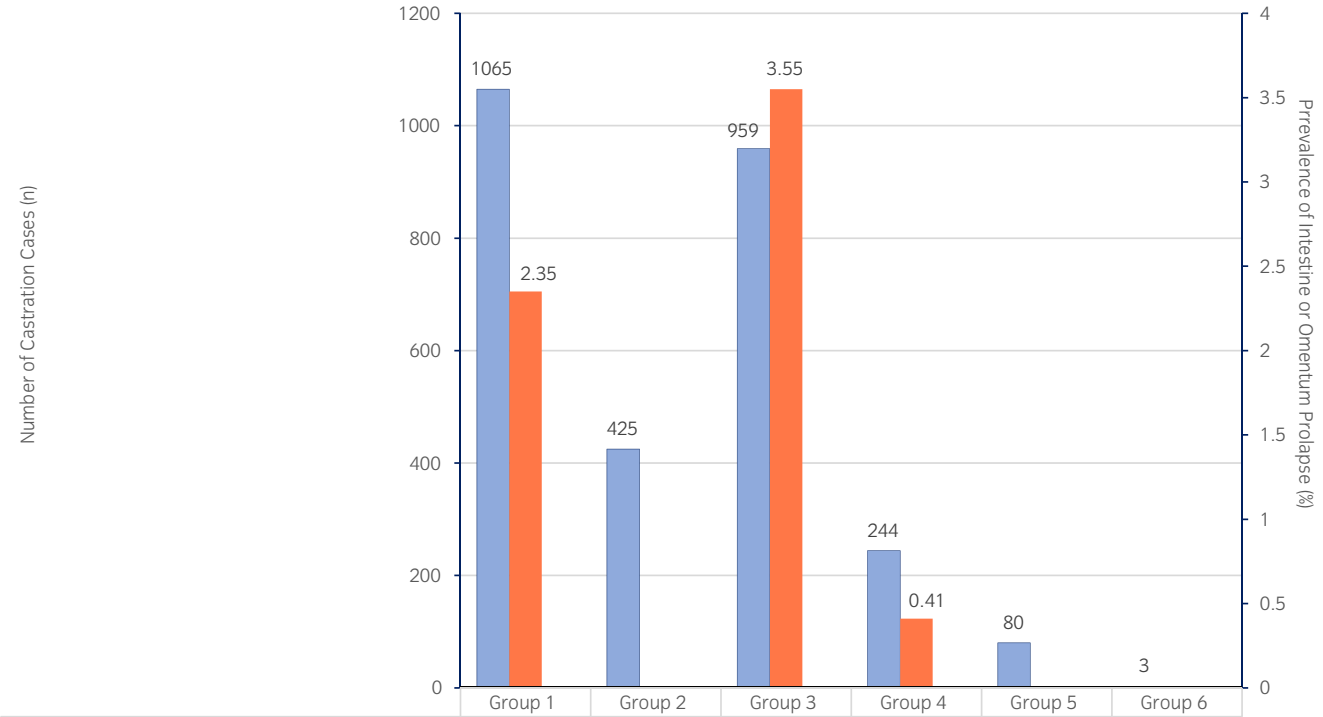
The risk of evisceration has been shown to be comparable between the open and closed techniques[10]; however, we need further information regarding the parietal tunic status to effectively make comparisons. This review indicated the risk of evisceration is much higher when the parietal tunic is left open at the end of the surgery, with only one case of evisceration reported when a ligature was placed from a total of 60 evisceration cases (Figure 2). If the parietal tunic is appropriately closed during castration, the risk of evisceration appears to be minimal. Evisceration cases were overrepresented by Standardbreds and draught breeds, although it is important to note that the quality or bias of included studies has not been fully evaluated. Further research is required to determine the statistical strength of this finding. It is our recommendation to close the parietal tunic if there is a suspected increased risk of evisceration.

A future classification system to categorise the surgical technique utilised for routine castration is proposed in Table 5 to eliminate any uncertainty surrounding the terms 'open' and 'closed'. The classification system focuses on the two most relevant aspects of the surgical technique including whether any of the parietal tunic remains and whether the parietal tunic is sutured and considered closed at the end of surgery. Having a clear reporting system will potentially enhance future research by providing consistency and clarity and enabling meta-analysis of combined datasets in the future.

Castration can be performed standing or recumbent, with a range of approaches and techniques, with or without the use of ligatures and with the option of leaving the surgical sites open to heal by second intention or closing them. Specific instrumentation can also be used for castration. The most common of these is emasculators with 19 of 25 papers utilising them. The Equine Henderson Castration Instrument (EHCI)[3,5] and LSA device[29] were also reported in place of emasculators. Laparoscopy has been proposed for use in normal descended testicles,[43] although no cases were identified in this review, likely due to most studies leaving the testicles in situ.

There is a lack of consensus on what is considered a complication and what is considered a 'normal' surgical consequence of castration. Complications such as evisceration, septic funiculitis and surgical site infection are clearly considered abnormal (although there were variations in how infection was defined). For common problems, such as haemorrhage and swelling, an element of this can be considered 'normal' depending on the technique.[20,32,39] Understanding the point at which swelling and haemorrhage become abnormal is vague and alters individual interpretation. Within equine practice, haemorrhage, oedema, pyrexia, pain and some tissue protrusion are often considered acceptable or a normal post-castration finding and many papers do not include these as complications, varying in how they define and categorise them. It should be noted that these complications would not be considered normal in other species, such as the dog or man. Complication rates are also highly dependent on how they are monitored and reported, for example, whether pain and swelling is assessed by the attending vet or the owner in the subsequent hours or days. It is, therefore, very likely that complications associated with equine castration are under-reported and have a higher incidence than what is reported in the literature.

Any infection following castration is a complication. Once again, how infection is defined fluctuates between studies. Swelling with pyrexia and discharge that requires treatment is included in most definitions of surgical site infections, but that was not universally applied in castration studies.[6,12,25] Purulent discharge from the incisions was required to define a surgical site infection in one study,[28] whereas this was not essential for other studies. One survey from 1995 concluded that higher infection rates were reported when ligatures around the spermatic cord were used.[35] According to a later survey, vets refer to this study as to why they prefer not to place a ligature.[44] From the 25 studies in this review, there are more reports of septic funiculitis in cases of non-sutured spermatic cords to sutured. Suggestions that leaving the parietal tunic in situ increases cases of septic funiculitis have also been made.[45] In a study of 238 equids, no cases of septic funiculitis were reported following an open technique,[11] although this may be from a lack of reporting.



	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Number of Castration Cases (n)	1065	425	959	244	80	3
Number of Evisceration Cases in Each Group	25	0	34	1	0	0
Prevalence of Intestinal or Omental Evisceration within group (%)	2.35	0	3.55	0.41	0	0

FIGURE 2 A bar graph to show the number of cases of domesticated equids castrated within each surgical technique group and the number of intestinal or omental eviscerations reported in a scoping review of castration complications in domesticated equids. This graph displays the data extrapolated from studies in this scoping review on evisceration cases and the surgical techniques used. Groups 2, 4 and 6 all had ligatures placed during castration to close the parietal tunic and there was only 1 evisceration case out of 672 castrations. The parietal tunic in Groups 1, 3 and 5 remained open at the end of surgery and 59 evisceration cases out of 2104 castrations were recorded.

The studies in this review did not show any clear trend towards the use of sutures being associated with increased risk of infection, but it is clear that the definition and reporting of infection need standardising. During one study, six cases were excluded from the results due to having a high preoperative serum amyloid A (SAA) of more than 10 mg/L.[25] Interestingly, three of six (50%) developed a postoperative infection, two surgical site infections and one septic funiculitis. This suggests SAA levels could serve as an indicator for increased infection risk following surgery, highlighting the potential value of taking preoperative biomarkers like SAA. Further research to explore this association is necessary.

4.2 | Analgesia

There is clear evidence that surgical castration induces a significant pain response in equids, as demonstrated by high pain scores and various biomarkers.[46–50] However, perioperative analgesia is very variable between studies, with 2 of 25 papers lacking any analgesic provision and a further six papers not stating whether any analgesia was administered (Table 3). This is concerning, as a survey in 2018 also revealed that 25% of veterinarians did not administer any analgesia.[44]

Local anaesthetic has been shown to reduce postoperative pain.[46,51] When combined with flunixin, it is superior to using flunixin alone for pain reduction.[52] In addition, intrafunicular anaesthesia was reported to be more effective at lowering postoperative IL-6 and TNF-α compared with intratesticular.[51] The exact number of horses experiencing postoperative pain is unknown. Mild pain may be undetected or unreported by owners and most studies accept an element of pain as a normal post-castration finding. Flunixin has been reported to be superior to meloxicam and firocoxib for analgesia.[28] Although in one study, signs of colic interpreted as postoperative pain were reported in 8.8% of stallions, despite preoperative flunixin, intraoperative morphine and postoperative phenylbutazone.[11] This was the only study to report the use of morphine for analgesia.

There is enough evidence, alongside the British Equine Veterinary Association (BEVA) guidelines, based on a systematic review of NSAIDs, to conclude that preoperative administration of NSAIDs should be carried out prior to surgery and continued for at least 3 days after surgery.[53] Local anaesthesia should be utilised for horses undergoing general anaesthesia and not just standing castrations.[53] The use of preoperative butorphanol alone is not adequate analgesia and buprenorphine, although it provides some analgesia, should not be relied upon as the sole analgesic agent.[53] These minimum

TABLE 5 A table to display a classification system for the surgical castration technique of domesticated equids.

Classification of surgical castration technique	Definition
Type 1a	The parietal tunic is incised to exteriorise the testicle, cutting the ligament of the tail of the epididymis, and transecting the spermatic cord. None of the parietal tunic is removed. There is no closure of the parietal tunic.
Type 1b	The parietal tunic is incised to exteriorise the testicle, cutting the ligament of the tail of the epididymis, and transecting the spermatic cord. None of the parietal tunic is removed. Ligatures are placed to close the parietal tunic.
Type 2a	The testicle is removed within the parietal tunic or an incision is made into the parietal tunic to expose and inspect the contents, and a portion of the parietal tunic is removed alongside the testicle. There is no closure of the parietal tunic.
Type 2b	The testicle is removed within the parietal tunic or an incision is made into the parietal tunic to expose and inspect the contents, and a portion of the parietal tunic is removed alongside the testicle. Ligatures are placed to close the parietal tunic.

recommendations were not followed in a significant number of studies. Standardised recording of perioperative treatment and pain scoring is also required to improve the evidence base.

4.3 | Antimicrobials

Appropriate antimicrobial use in equine medicine is crucial due to the emergence of multi-drug-resistant microbes and regulators have become concerned with prophylactic use.[54] Sub therapeutic levels are thought to contribute to resistance.[54] Surgery should firstly be classified as clean, clean-contaminated, contaminated, or high risk before deciding on antimicrobial protocol.[55] There is no evidence to support the use of antimicrobials preoperatively for a clean surgery,[55,56] and Australian guidelines advise no preoperative antimicrobials are required for field castration.[57] Standing castrations can be difficult to maintain a clean aseptic surgical site, both in an ambulatory and a hospital setting. In these situations, prophylactic antimicrobials may be indicated, although they should not be used to replace aseptic surgical techniques.

Administering penicillin perioperatively resulted in a significantly lower SAA postoperatively[25,30]; however, no conclusion was made if antimicrobials reduce infection rates. Overall, no two papers used the same antimicrobial protocol which creates difficulty when comparing literature.

It has been reported throughout the literature that to prevent surgical site infections, antimicrobials must be present at effective concentrations when the first incision is made.[54] The guidelines for human medicine advise, in general, for antimicrobials to be administered within 60 min of the first incision, and for some groups, such as fluoroquinolones, up to 120 min before the first incision.[58] Studies have revealed that the therapeutic concentrations of intravenous gentamicin and sodium penicillin reach peak levels at the surgical site within 15–30 min.[59,60] A separate study found that intra-muscular procaine benzylpenicillin can take up to 4 h to reach peak effect.[61] The timing of administration before surgery is an important factor in ensuring peak efficacy is achieved, although these will invariably change depending on several factors, including dose and route of administration.

Using the 'BEVA protect me tool kit', penicillin would be an appropriate first-line choice if antimicrobials were indicated and there is no indication for postoperative antimicrobials.[62] Using this guide, ceftiofur is considered an inappropriate choice for castration. This is further supported by the World Health Organisation, classifying third and fourth-generation cephalosporins as Highest Priority Critically Important Antimicriobials confirming ceftiofur is inappropriate to use prophylactyically.[63] Penicillin and gentamicin combined should only be utilised when the surgery is classified as contaminated. Procaine benzylpenicillin is a time-dependent antimicrobial and should be given intramuscularly every 12 h if continued postoperatively.[54] There were six studies identified in this review using procaine benzylpenicillin intramuscularly every 24 or even 48 h. Antimicrobials are not required preoperatively for a clean surgery. If preoperative antimicrobials are used, they should be administered with enough time to reach sufficient concentrations at the surgical site before the first incision.

4.4 | Limitations

Scoping reviews do not assess the validity or method quality of included studies, causing an obvious limitation when interpreting clinical findings. The risk of bias was also not assessed in this review. This study did not include grey literature or studies where there was no English translation, and studies where the full text was not available were excluded. This may have excluded some studies which had suitable data for analysis. Grey literature is not peer-reviewed, therefore, would be excluded using the eligibility criteria. It is likely that incidence rates of serious complications may be higher than reported within the published literature. It is more beneficial to source from grey literature when negligible results are found using search databases, for instance, in drug trials. The chosen search databases were found in accordance with a study that analysed the coverage of veterinary journals by bibliographic databases, revealing CAB abstracts give almost complete coverage of veterinary journals and is the recommended database for these reviews.[17]

The search terms were constructed by all authors and reviewed by a librarian, although it is possible due to the breadth of terms for the numerous complications that not all papers were found. Another limitation was the inconsistency in reporting of surgical technique and

outcomes across different papers which reduced the data available for analysis. A number of relevant papers were charted separately as although they included data on various complications, the original castration technique and protocols were all grouped together or the population also contained cryptorchids, so a technique or protocol could not be directly associated with the specific complication.[8,35,44,64–66] Some studies also stated the technique used but did not give any description, and it was assumed that the technique stated was correct. Cryptorchids and castration leaving the testicles in situ were both excluded from this review because the surgical techniques differ and all authors felt the complications observed could alter the results of this review.

5 | CONCLUSION

This scoping review assembled and condensed the literature available on complications following castration of equids, with two testicles descended into the scrotum. The existing studies report similar methodologies and aims, however vary greatly in the surgical technique used and in the perioperative management, and there is a clear lack of consensus on what is considered a complication. A universal standard to define the complications would help to reduce variability associated with individual interpretation. Consistent definitions are necessary for vets and owners to distinguish between normal postoperative outcomes and what is considered a complication. There are multiple large population studies published in this area,[2–5,10,12,13,64] although it is problematic to draw meaningful conclusions due to variations between perioperative protocols and surgical techniques and a lack of reporting of defined outcomes from specific populations.

The definitions for surgical technique are mostly used correctly in this review; however, it is challenging to compare techniques solely based on an open, closed, or half-closed technique. There is a need for a new classification system when reporting surgical technique, to include additional information on whether the parietal tunic is open or closed at the end of surgery, and this is proposed in Table 5. This study also highlighted issues with analgesia and antimicrobial use for castration in the horse, which have implications for equid welfare and antimicrobial resistance and must be addressed going forwards. A large multicentre prospective study is essential to further assess risk factors for castration complications.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interests.

AUTHOR CONTRIBUTIONS

Elise B. K. Rodden: Investigation; funding acquisition; writing – original draft; methodology; validation; visualization; writing – review and editing; software; formal analysis; project administration; data curation; resources. **Joanna M. Suthers:** Methodology; writing – review and editing. **Evita Busschers:** Writing – review and editing; methodology. **John H. Burford:** Writing – review and editing; methodology; funding acquisition. **Sarah L. Freeman:** Investigation; funding acquisition; methodology; writing – review and editing; supervision; data curation; validation; project administration; formal analysis; writing – original draft.

DATA INTEGRITY STATEMENT

Elise Rodden and Sarah Freeman had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of data analysis.

ETHICAL ANIMAL RESEARCH

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DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analysed in this study.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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