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Valveless and conventional insufflation on pneumoperitoneum-related complications in robotic partial nephrectomy: a systematic review and meta-analysis of prospective studies

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Abstract

Introduction The use of pneumoperitoneum is an essential step for performing laparoscopic and robotic surgery. Pneumoperitoneum insufflation can cause complications such as pneumothorax, subcutaneous emphysema, and pneumomediastinum. The purpose of this meta-analysis is to compare the safety of using the conventional insufflation system versus a Valveless insufflation system as devices for manufacturing pneumoperitoneum in robotic-assisted nephrectomy.

Methods A comprehensive literature search was conducted on PUBMED, EMBASE, SCOPUS, and Cochrane, from inception until January 2024. Randomized and nonrandomized prospective studies were included in the meta-analysis, performed by the R+ Rstudio.

Results Three publications encompassing 478 patients were included. We observed no difference in SCE (OR 0.60, CI 95% 0.27;1.34, $p=0.134$, $I^2=0$), PNM (OR 0.82, CI 95% 0.24;2.78, $p=0.558$, $I^2=0$), When comparing groups conventional insufflation system (CIS) versus AirSealTM insufflation system (AIS) with pneumoperitoneum pressure of 15 mmHg or 12 mmHg.

Conclusion The presented data showed no difference between the AIS when compared with CIS in Pneumoperitoneum insufflation-related complications.

Keywords Valveless, Standard insufflation, Robot-assisted, Partial nephrectomy, Neumoperitoneum insufflation-related complications

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Introduction

Minimally invasive surgery, including either traditional laparoscopic and robot-assisted laparoscopic approaches to renal surgery have been widely used. When compared to open surgery, results show less postoperative pain, shorter hospital stay, and less blood loss [1, 2]. However, despite its safety, pneumoperitoneum insufflation, in which carbon dioxide is usually used, can cause metabolic and hemodynamic changes, as well as complications.

Pneumoperitoneum insufflation-related complications (PIC) occur because CO2 dissects the subcutaneous tissue and fascia, and can cause subcutaneous emphysema (SCE), pneumothorax (PTX) and, more rarely, pneumomediastinum (PMS) [3]. These complications can lead to such clinical changes as metabolic acidosis and hypercarbia [4–6]. Although SCE has a rate of 12.5% to 45% in laparoscopic kidney and adrenal surgeries after radiographic studies, fortunately, it is a self-limiting complication in the vast majority of cases [4, 7]. The occurrence of PTX and PMS can be explained by the presence of congenital diaphragmatic channels and the passage of gas through the foramen of the inferior vena cava [8–10].

Factors related to the presence of PIC are the interaction of gas volume used, insufflation exposure time, gas flow rate, increased intra-abdominal insufflation pressure, and factors related to the patient and the trocar insertion [4, 11].

The insufflation of pneumoperitoneum is a fundamental step of the robotic-assisted PN, and can be done by 2 systems: conventional insufflation system (CIS) and valveless insufflation; The second one, the AirSealTM insufflation system (AIS) (CONMED, Utica, NY) is a valveless trocar system, that enables a stable pneumoperitoneum with continuous smoke evacuation and CO^2 recirculation during surgery, reducing CO2 absorption and consumption [11]. Previous studies, in urological surgery, found superiority in the stability of pneumoperitoneum when AIS is used compared to CIS [12–14].

This meta-analysis aims to compare the incidence of PIC in robotic partial nephrectomy when using AIS vs. CIS, composed exclusively of prospective studies on the topic.

Material and methods

Eligibility criteria

This study was registered at Prospero CRD42024508682. A search was conducted at PubMed/MEDLINE, Embase, Cochrane, and Scopus data-bases from its inception to January 2024 to identify Prospective Studies, reporting the Comparison of valveless and standard insufflation on pneumoperitoneum-related complications in robotic partial nephrectomy for various causes. Our outcomes of interest were the rate of SCE and PMS.

Search strategy and data extraction

We systematically searched PubMed, Embase, Cochrane, and Scopus Central Register of Prospective Studies from inception to January 2024 with the following search terms: ('valve less' OR 'valveless' OR 'Standard Insufflation') AND ('Robotic Partial Nephrectomy' OR 'robot-assisted partial nephrectomy'). Zotero was utilized to remove any duplicate studies. Two independent researchers conducted a screening of titles and abstracts to eliminate irrelevant studies. Following this process, the full text was reviewed to select the included studies. Any disagreements were solved by a third reviewer.

Quality assessment

Data was independently extracted from the included studies by two authors. Any discrepancies among the extracted data were resolved by discussion with a third reviewer. The Rob2 tool [15] was used to assess the quality of the RCTs and ROBIN-1 was used to assess the quality of non-RCTs.

Statistical analysis

The meta-analysis was performed by the R + Rstudio (*RStudio Team (2023). Rstudio: Integrated Development for R. Rstudio, PBC, Boston, MA*) [15]. Dichotomous data are presented as Odds Ratio with 95% CI. Pooled estimates were calculated with the random-effect model, considering that the patients came from different populations. For all statistical analyses, a two-sided value of $p < 0{,}05$ was considered statistically significant. The I^2 statistic and the p-value tests were used to assess heterogeneity.

Results

Study selection and characteristics

The search retrieved 23 articles. After screening, 4 Prospective studies were included in this meta-analysis (Fig. 1). In total, 478 patients were included, and data as baseline characteristics, device type, age and gender. Two different pneumoperitoneum pressure values were used among the studies (15 mmHg and 12 mmHg) (Table 1).

Subcutaneous emphysema (SCE)

AIS was no different when compared to CIS method in our primary outcome (SCE) (OR 0.60, CI 95% 0.27;1.34, $p = 0.134$, $I^2 = 0$) (Fig. 2).

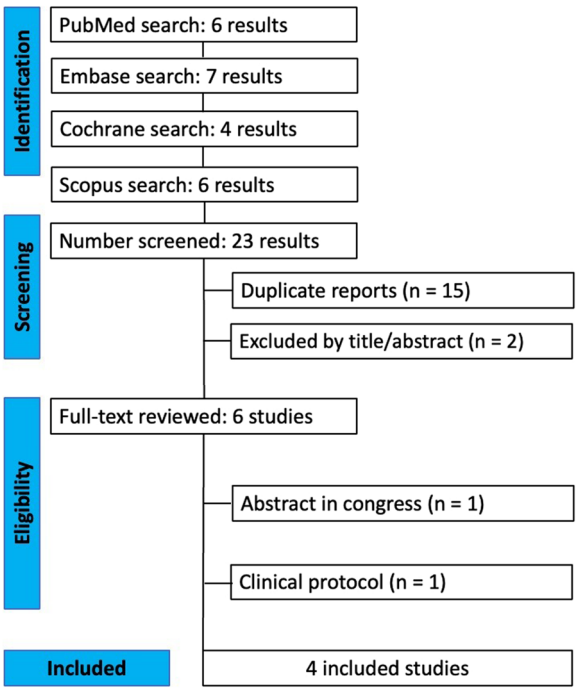

Fig. 1 Prisma flow diagram

Pneumothorax (PTX)

It was not possible to evaluate pneumothorax rates through meta-analysis because one of the studies did not present the complication in any of the groups [12].

Pneumomediastinum (PMS)

AIS was no different when compared to CIS method in our primary outcome (PMS) (OR 0.82, CI 95% 0.24;2.78, $p=0.558$, $I^2=0$ (Fig. 3).

Risk of bias

The only trial non-RCT [12] was assessed by Robins-I score, ant it presented a moderate risk of bias (Fig. 4A). On the other hand, the RCTs trials were assessed through Rob-2 tool, which presented a low overall score of bias in Desroches 2021 trial, and a moderate risk in the Feng's 2021 study (Fig. 4B).

Discussion

In our meta-analysis, we included 478 patients from 4 different Prospective Studies comparing AIS vs CIS, who underwent robotic PN, using Pneumoperitoneum pressure of 15 mmHg or 12 mmHg. We observed that AIS

Table 1 Baseline characteristics of included studies

Study	Design	Pneumoperitoneum	Pressure	Airseal/standard	Mean Age (y) ± SD / airseal / standard	Gender (%), male / female / airseal / standard	Pneumothorax airseal / standard
Annino et al., 2017 [12]	Cohort	Airseal versus standard	15 mmHg	67/55	66.2 (6.8) / 67 (7.9)	M: 70% / 74,5% F: 30% / 25,5%	0 / 0
Desroches et al., 2021 [16]	RCT	Airseal versus standard	15 mmHg	69/66	60.1(11.8) / 60 (12.5)	M: 62% / 65% / F: 38% / 35%	3 (5%) / 3(5%)
Feng et al., 2021 [17]	RCT	Airseal versus standard	15 mmHg	31/31	60.4 (12) / 61 (11.6)	M: 58% / 61% / F: 42% / 39%	1 (3,2%) / 3 (9,6%)
Wei et al., 2024 [18]	RCT	Airseal versus standard	12 mmHg	31/31	56.1 (4.6) / 53.7 (3.9)	M: 64.5% / 54.8% F: 45.2% / 35.5%	-

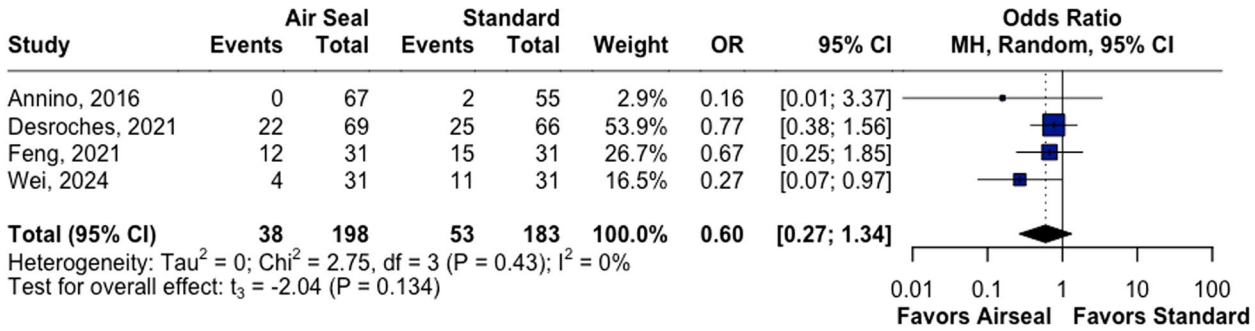

Fig. 2 AirSeal versus Standard group pneumoperitoneum insufflation, no difference in SCE complication. A Forest plot of subcutaneous emphysema SCE (enfisema subcutâneo), CI, confidence

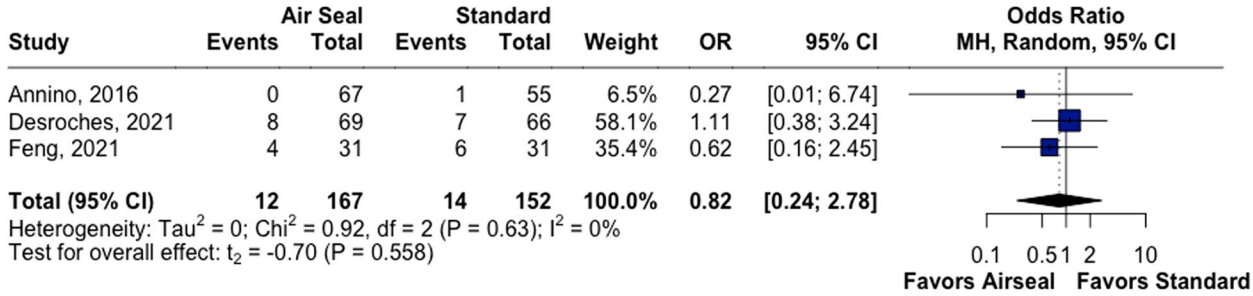

Fig. 3 AirSeal versus Standard group pneumoperitoneum insufflation, no difference in PMS complication. A Forest plot of pneumomediastinum PMS (pneumomediastino), CI, confidence interval

(A) Risk of bias summary for non-randomized studies (ROBINS-I)

Study	Bias due to confounding	Bias in selection of participants	Bias in classification of interventions	Bias due to deviations from intended interventions	Bias due to missing data	Bias in measurement of outcomes	Bias in selection of he reported results	**Overall risk of bias judgement**
Annino, 2016	!	!	+	+	+	!	+	!

(B) Risk of bias summary for randomized studies (ROB-2)

Study	Bias from randomization process	Bias due to deviations from intended interventions	Bias due to missing outcome data	Bias due to measurement of the outcomes	Bias in the selection of the reported result	**Overall risk of bias**
Desroches, 2021	+	+	+	+	+	+
Feng, 2021	!	!	+	+	+	!
Wei, 2024	+	!	+	+	+	+

Fig. 4 Risk of bias of the included studies (ROBINS-1) and (ROB-2). Risk os bias (robins1). **A** Risk of bias summary for non-randomized studies (ROBINS-I). **B** Risk of bias summary for randomized studies (ROB-2). C Risk of bias summary for randomized studies (ROB-2)

was not superior to CIS regarding PIC, such as SCE e PMS.

American Urological Association and European Association of Urology have no position regarding the optimal technique for pneumoperitoneum. Increased intra-abdominal insufflation pressure is a cause of complications such as subcutaneous emphysema and periodic episodes of blood pressure peaks during its use. Thus, the AIS emerges as a device with a theoretical benefit over these complications. Although the use of AIS versus the CIS method boasts, in the AIS group, a lower rate of complications in the AIS group, as PTX, SCE, and PMS, this difference has not been statistically proven [17].

Of the 4 studies evaluated in this work, only Desroches et al. statistically demonstrated the superiority of AIS versus CIS in SCE when comparing pneumoperitoneum pressure of 12 mmHg versus 15 mmHg. There was no superiority in other complications between the pressure of 12 mmHg versus 15 mmHg and 15 mmHg versus 15 mmHg in AIS versus CIS [12, 16, 17, 19]. Wei et al. demonstrated that there is an association between airseal and lower rates of subcutaneous emphysema when using pressures of 12 mmHg [18]. Recently a meta-analysis [20], was published and showed that the use of airseal would be associated with lower rates of subcutaneous emphysema and pain after surgery. We did not find this association.

PTX is one of the most feared complications of laparoscopic surgeries, which can lead the patient to a relevant clinical complication and consequently to an

unscheduled outcome. The main causes for such complication are: simple gas diffusion, iatrogenesis, anatomical defects [21]. The main risk factors involved in the genesis of PTX during laparoscopic surgery are surgical time > 200 min, positive end tidal CO2 > 50 mmHg, and operator inexperience [22–24].

The rate of PTX was not evaluated since one of the selected studies did not present cases of PTX. Further studies should be carried out to evaluate the rate of PTX during robotic PN, when using AIS vs. CIS.

Conclusion

The synthesis of the available evidence showed no difference between the AIS when compared with CIS in Pneumoperitoneum insufflation-related complications. However, the results suggest that with a higher N, the comparison in vogue would be statistically significant. More RCTs are necessary to ratify our findings.

Abbreviations

PIC	Pneumoperitoneum Insufflation-related Complications
CO2	Carbon Dioxide
SCE	Subcutaneous Emphysema
PTX	Pneumothorax
PMS	Pneumomediastinum
CIS	Conventional Insufflation System
AIS	AirSeal Insufflation System
PN	Partial Nephrectomy
Rob2	Cochrane Risk of Bias Tool Version 2
RStudio	Integrated Development Environment for R
PBC	Public Benefit Corporation
I2	Heterogeneity Statistic

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Nothing to declare.

Authors' contributions

Richard Dobrucki de Lima conceived, screened the papers, and wrote. Lucas Schenk de Almeida screened the papers and wrote. Breno Cordeiro Porto and Carlo Passerotti screened the papers. José Pinhata Otoch supervised. José Arnaldo Shiomi da Cruz and Rodrigo Afonso da Silva Sardenberg supervised and guided.

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Not applicable.

Data availability

Data is provided within the manuscript in Table 1 (at the end of the document).

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

All authors have reviewed and approved the manuscript for publication.

Competing interests

The authors declare no competing interests.

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