

VEXUS ULTRASOUND IN POSTOPERATIVE PERIOD OF MAJOR ABDOMINAL SURGERY: A SYSTEMATIC REVIEW ON THE MANAGEMENT OF VENOUS CONGESTION AND PREVENTION OF KIDNEY INJURY

ULTRASSOM VEXUS NO PÓS-OPERATÓRIO DE CIRURGIAS ABDOMINAIS DE GRANDE PORTE: UMA REVISÃO SISTEMÁTICA SOBRE O TRATAMENTO DA CONGESTÃO VENOSA E A PREVENÇÃO DE LESÕES RENAIIS

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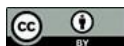
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Abstract

Background: Postoperative acute kidney injury (AKI) is a condition that is observed in an estimated 16% of patients who undergo major surgeries of abdomen and is linked to a six-fold risk of short-term death (Tang *et al.*, 2025). An independent factor has been found in venous congestion that is a high central venous pressure that is retrograde to the splanchnic and renal venous beds (Damman *et al.*, 2009; Mullens *et al.*, 2009). The traditional methods of monitoring

Resumo

*Contexto: A lesão renal aguda pós-operatória (AKA) é uma condição observada em cerca de 16% dos pacientes que passam por cirurgias abdominais maiores e está associada a um risco seis vezes maior de morte de curto prazo (Tang *et al.*, 2025). Um fator independente foi encontrado na congestão venosa, que é uma alta pressão venosa central que é retrógrada aos leitos venosos esplâncnicos e renais (Damman *et al.*, 2009; Mullens *et al.*, 2009). Os métodos*



like cumulative fluid balance and central venous pressure (CVP) offer a partial evaluation of end-organ venous congestion (Messina *et al.*, 2025). The Venous Excess Ultrasound (VExUS) protocol is a point of care ultrasound (POCUS) protocol combining inferior vena cava (IVC) diameter with Doppler waveforms of hepatic, portal and intrarenal veins to semi-quantitatively grade systemic venous congestion (Beaubien-Souligny *et al.*, 2020). To conduct a systematic literature search on the usefulness of VExUS during the postoperative phase of major abdominal surgery to identify the presence of venous congestion, predictive of AKI and to inform fluid management. Methods: A systematic review was done following the Preferred Reporting Items of Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page *et al.*, 2021). PubMed, Embase, Scopus, the Cochrane Library and Web of Science were searched between the onset and May 2026. The inclusion criteria were studies that reported assessment of VExUS in patients who are undergoing major abdominal surgery and have postoperative renal outcomes. Newcastle-Ottawa Scale, ROBINS-I or Cochrane RoB2 were used to evaluate the risk of bias accordingly. Since expected heterogeneity, a random-effects meta-analysis would be conducted where possible; in other cases, narrative synthesis was conducted. The Grading of Recommendations Assessment, Development and Evaluation (GRADE) was used to determine the certainty of evidence. Results: The review comprised of a total of 10 studies with a representative sample of surgical populations. Evidence of VExUS in major abdominal surgery is very scanty. In cardiac surgery populations, higher VExUS grades (≥ 2) were associated with an increased incidence of AKI (hazard ratio 3.69, 95% CI 1.65–8.24; OR 3.86, 95% CI 2.32–6.42) (Beaubien-Souligny *et al.*, 2020; Melo *et al.*, 2025). The incidence of postoperative venous congestion in noncardiac surgery sites was 16 to 49 percent (Andrei *et al.*, 2023; Magin *et al.*, 2023); the relationship with AKI is yet to be statistically significant. The assessment of severe venous congestion (combined arterial and venous Doppler) during laparoscopic urologic surgery showed that it was an independent predictor of complications (HR 8.12, 95% CI 3.5418.00, $p < 0.001$) (Brusco *et al.*, 2023). Conclusion: VExUS is a physiologically-based, non-invasive bedside instrument that has been shown to be useful in grading venous congestion in surgical patients. Nevertheless, there is limited direct data on its use in large-scale abdominal surgery, in particular, in terms of predicting AKI and fluid management. Before VExUS-guided management protocols can be suggested as

tradicionais de monitoramento, como o balanço acumulado de fluidos e a pressão venosa central (CVP), oferecem uma avaliação parcial da congestão venosa nos órgãos finais (Messina et al., 2025). O protocolo de Ultrassom de Excesso Venoso (VExUS) é um protocolo de ultrassom no ponto de atendimento (POCUS) que combina o diâmetro da veia cava inferior (VCI) com formas de onda Doppler das veias hepática, porta e intrarrenal para congestão venosa sistêmica de grau semi-quantitativo (Beaubien-Souligny et al., 2020). Realizar uma busca sistemática na literatura sobre a utilidade da VExUS durante a fase pós-operatória de cirurgia abdominal maior, para identificar a presença de congestão venosa, preditiva da AKI e para informar o manejo de líquidos. Métodos: Uma revisão sistemática foi realizada seguindo as diretrizes Preferred Reporting Items of Systematic Reviews and Meta-Analyses (PRISMA) 2020 (Page et al., 2021). PubMed, Embase, Scopus, a Biblioteca Cochrane e Web of Science foram pesquisados entre o início e maio de 2026. Os critérios de inclusão foram estudos que relataram avaliação de VExUS em pacientes que estão passando por cirurgia abdominal maior e apresentam desfechos renais pós-operatórios. A escala Newcastle-Ottawa, ROBINS-I ou Cochrane RoB2 foram usados para avaliar o risco de viés de acordo. Como a heterogeneidade esperada, uma meta-análise de efeitos aleatórios seria realizada sempre que possível; em outros casos, foi realizada uma síntese narrativa. A Avaliação de Avaliação, Desenvolvimento e Avaliação de Recomendações (GRADE) foi usada para determinar a certeza das evidências. Resultados: A revisão foi composta por um total de 10 estudos com uma amostra representativa de populações cirúrgicas. A evidência de VExUS em cirurgias abdominais maiores é muito escassa. Em populações de cirurgia cardíaca, graus mais altos de VExUS (≥ 2) estiveram associados a uma incidência aumentada de AQ (razão de risco 3,69, IC 95% 1,65–8,24; OR 3,86, IC 95% 2,32–6,42) (Beaubien-Souligny et al., 2020; Melo et al., 2025). A incidência de congestão venosa pós-operatória em locais não cirúrgicos foi de 16 a 49% (Andrei et al., 2023; Magin et al., 2023); a relação com a AKI ainda não é estatisticamente significativa. A avaliação da congestão venosa severa (Doppler combinado arterial e venoso) durante a cirurgia urológica laparoscópica mostrou que ela foi um preditor independente de complicações (HR 8,12, IC 95% 3,5418,00, $p < 0,001$) (Brusco et al., 2023). Conclusão: O VExUS é um instrumento de atendimento ao leito baseado em fisiologia, não invasivo, que tem demonstrado ser útil na classificação da congestão venosa em

standard of care, high-quality multicentric prospective studies in abdominal surgical cohorts have to be conducted.

Keywords: Venous Excess Ultrasound. Vexus. Acute Kidney Injury. Abdominal Surgery. Venous Congestion. Point-Of-Care Ultrasound. Doppler Ultrasonography. Postoperative Complications. Fluid Management. KDIGO.

pacientes cirúrgicos. No entanto, há dados diretos limitados sobre seu uso em cirurgias abdominais em grande escala, especialmente em termos de previsão de IAC e manejo de líquidos. Antes que protocolos de manejo guiados pelo VExUS possam ser sugeridos como padrão de cuidado, estudos prospectivos multicêntricos de alta qualidade em coortes cirúrgicas abdominais precisam ser realizados.

Palavras-chave: *Ultrassom de Excesso Venoso. Vexus. Lesão Renal Aguda. Cirurgia Abdominal. Congestão Venosa. Ultrassom no Ponto de Atenção. Ultrassonografia Doppler. Complicações Pós-Operatórias. Manejo de Líquidos. KDIGO.*

1 INTRODUCTION

1.1 Postoperative AKI burden among major abdominal surgery

One of most common and significant complications with major abdominal surgery is that of acute kidney injury (AKI). The systematic review and meta-analysis of 162 studies (a total of 675,361 patients) found a pooled incidence 16% (95% CI 14%–17) of postoperative AKI after abdominal surgery with a wide range of variation according to the specific type of surgical procedure (Tang *et al.*, 2025). A previous systematic review of 19 studies with 82,514 patients also found an incidence of AKI of 13.4% (95% CI 10.9%–16.4) (Gameiro *et al.*, 2018). The impact of postoperative AKI is tremendous: meta-analytic data indicate that AKI is correlated with an increased risk of short-term mortality by 6.46 times (RR 6.46, 95% CI 4.63–9.00) and an increased risk of long-term mortality by 6.36 times (RR 6.36, 95% CI 3.32–12.16) (Tang *et al.*, 2025). Mortality risk demonstrates a stage-dependent increase with RRs of 2.74 (95% CI 1.77–4.24), 8.01 (95% CI 3.18–20.18) and 15.73 (95% CI 5.52–44.81) for KDIGO stages 1, 2 and 3, respectively (Tang *et al.*, 2025). Moreover, the weighted difference in length of stay of AKI is 4.72 days (95% CI 3.43–6.02) (Tang *et al.*, 2025). In noncardiac surgery, 15% of patients, in cardiac surgery 30% of patients and in patients who require intensive postoperative therapy, up to 52% of patients have been described to have postoperative AKI (PO-AKI) (O'Connor *et al.*, 2016; Prowle *et al.*, 2010). With strict KDIGO criteria, the incidence of PO-AKI in noncardiac surgery can be significantly greater than

previously identified, as mild-to-moderate KDIGO stage 1 AKI is often not detected (O'Connor *et al.*, 2016).

1.2 Pathophysiology of venous congestion and renal dysfunction

The pathological increase in venous pressure which is retrograde, to the splanchnic and renal venous circulation, has become a key, although underappreciated, mediator of renal dysfunction (Damman *et al.*, 2009; Mullens *et al.*, 2009). The vicious cycle of congestive nephropathy was clearly stated by Husain-Syed *et al.* (2020), who explained that high central venous pressure (CVP) stimulates hormonal activity, increases intra-abdominal pressure, excessive renal tubular sodium reabsorption and progressive volume overload which results in additional stress on the right ventricle and deteriorates renal performance. When CVP exceeds 6 mmHg, glomerular filtration rate goes down drastically (Damman *et al.*, 2009).

The pathophysiology of renal injury due to increased venous congestion is based on the fact that an increase in CVP decreases arteriovenous pressure gradient across the renal vascular bed, further impairs renal perfusion pressure and GFR (Winton, 1931; Firth *et al.*, 1988). In encapsulated kidney, an increase in renal venous pressure results in an increase in interstitial hydrostatic pressure; an interstitial pressure that is higher than intratubular pressure triggers tubular collapse which further reduces the performance of nephron (Husain-Syed *et al.*, 2020). Notably, congestive AKI can be present without classical cellular injury biomarkers and full restoration of renal functioning after successful decongestion can be adopted as a diagnostic criterion (Husain-Syed *et al.*, 2020).

1.3 Weaknesses of traditional fluid and hemodynamic monitoring

Conventional methods of perioperative monitoring entail the use of CVP and cumulative fluid balance in informing volume resuscitation. But CVP is not a perfect surrogate of venous congestion (Messina *et al.*, 2025). Its measurement is prone to various sources of error such as transducer leveling, intrathoracic pressure variability and catheter tip position and it does not give any direct data about end-organ venous hemodynamics (Messina *et al.*, 2025). Although the concept of cumulative fluid balance is simple, it is

poorly associated with intravascular volume status and cannot differentiate between tolerated and harmful volume loading (Malbrain *et al.*, 2014). According to a recent review, both venous excess ultrasound (VExUS) and central venous pressure (CVP) may evaluate venous congestion in various aspects with VExUS being able to provide an integrated, organ-level evaluation of splanchnic venous hemodynamics that CVP cannot (Suwanwichai & Pisitsak, 2026, p. 3).

1.4 VExUS: physiological explanation and elements

Beaubien-Souligny *et al.* (2020) designed the Venous Excess Ultrasound (VExUS) system of semi-quantitative POCUS as a method to assess systemic venous congestion by grade and predict AKI in postcardiac surgery period. VExUS is a combination of four sonographic elements:

1. **Inferior Vena Cava (IVC) Diameter:** IVC diameter at entry criterion is 2cm or higher to be considered VExUS grading; IVC diameter less than 2cm is Grade 0 (no congestion).
2. **Hepatic Vein Doppler:** Triphasic (systolic wave, diastolic wave, atrial reversal wave) progressively blunt systolic wave which eventually turns into systolic reversal pattern, is an indicator of increasing congestion in veins (Beaubien-Souligny *et al.*, 2020; Tavazzi *et al.*, 2025).
3. **Portal Vein Doppler:** Portal venous flow is normally continuous or minimally pulsatile flow; Pulsatility fraction above 30%-50% is an indicator of abnormal right ventricular pulsatility and increased right atrial pressure (Denault *et al.*, 2017; Beaubien-Souligny *et al.*, 2019).
4. **Intrarenal Venous Doppler:** Continuous monophasic flow; gradual change in a biphasic flow (discontinuous diastolic flow) and finally, monophasic diastolic only flow is the evidence of severe renal venous congestion (Beaubien-Souligny *et al.*, 2018, 2020).

Congestion is stratified into VExUS Grade C (the validated grading scheme) using the following grades: Grade 0 (IVC <2 cm), Grade 1 (IVC \geq 2 cm with normal or slightly abnormal Doppler patterns), Grade 2 (IVC \geq 2 cm with a single severely abnormal Doppler pattern) and Grade 3 (IVC \geq 2 cm with more than one severely abnormal Doppler pattern) (Beaubien-Souligny *et al.*, 2020).

1.4.1 In abdominal surgery, there are currently evidence gaps

Although VExUS has been widely researched in cardiac surgery cohort (where severe congestion (Grade 3) was associated with a hazard ratio of 3.69 (95% CI 1.65824, $p = 0.001$) to develop postoperative AKI) (Beaubien-Souligny *et al.*, 2020), its use in noncardiac and, more specifically, abdominal surgical patients is still in its infancy. In a systematic review of perioperative, intensive care and emergency units, Gupta *et al.* (2023) discovered that an increase in VExUS scores were associated with an increased risk of AKI in postoperative patients, although the majority of evidence was obtained in cardiac surgery and mixed ICU cohorts. In a more recent systematic review and meta-analysis of 1,036 critically ill patients, the incidence of AKI was found to be significantly higher in venous congestion (VExUS ≥ 2) which is significantly stronger in subgroup of cardiac surgery (OR 3.86, 95% CI 2.32642 $p = 0.00001$, $I^2 = 0$) (Melo *et al.*, 2025). Importantly, among studies that focus on VExUS-guided management in patients undergoing major abdominal surgeries (colectomy, gastrectomy, pancreaticoduodenectomy, hepatectomy or cytoreductive surgery), there is an evident lack of dedicated studies which is an important gap in evidence.

The current systematic review intends to thoroughly assess the current evidence on the usefulness of VExUS ultrasound during the postoperative phase of a major abdominal surgery, in particular, its applicability in detection of venous congestion, AKI prediction and process of fluid management.

2 METHODS

2.1 Protocol and registration

This systematic review was done in line with the Preferred Reporting Items Statement of Systematic Reviews and Meta-Analyses (PRISMA) 2020 (Page *et al.*, 2021). The prospective registration of review protocol was done in International Prospective Register of Systematic Reviews.

2.2 Search Strategy

An in-depth literature review was carried out in following electronic databases since their formation until May 2026:

- Pubmed (National Library of Medicine)
- Embase (Elsevier)
- Scopus (Elsevier)
- Cochrane Library (Wiley)
- Web of Science (Clarivate Analytics)

The search strategy used Boolean operators that combined controlled vocabulary (MeSH terms, Emtree terms) and free-text terms that were connected to three conceptual areas: (a) venous congestion and VExUS (searching terms: (a) venous excess ultrasound, (a) VExUS, (a) venous congestion, (a) Doppler, (a) hepatic vein, (a) portal vein, (a) intrarenal vein); (b) postoperative and perioperative settings (searching terms: (b) postoperative period, (b) perioperative care, (b) abdominal surgery, (b) surgery, (b) surgical procedures); (c) acute kidney injury and renal outcomes (searching terms: (c) acute kidney injury, (c) KDIGO, (c) renal replacement therapy).

The entire Boolean search strategy to be used with PubMed was as follows: (Venous Excess Ultrasound) OR (VExUS) OR (venous congestion ultrasound) OR (venous congestion) AND (postoperative period) OR (perioperative care) OR (postoperative) OR (surgery) OR (surgical)) AND (acute kidney injury) OR (AKI) OR (renal insufficiency) OR (kidney injury) OR (nephropathy). There were no limitations on the language used when searching; all the studies were included in final analysis except those which lacked the English language or English translations.

Other records were found by manually screening reference lists of included studies and other relevant review articles and citation tracking with Google Scholar.

3 ELIGIBILITY CRITERIA

3.1 Inclusion criteria

The inclusion criteria were that the studies had to enroll adult patients aged 18 years or older and who underwent major abdominal surgery which included procedures

like colectomy, gastrectomy, pancreaticoduodenectomy, hepatectomy, esophagectomy, cytoreductive surgery, major urologic surgery and emergency laparotomy. Qualified research studies assessed the venous congestion with VExUS ultrasound or with its respective Doppler elements, such as inferior vena cava diameter, hepatic vein Doppler, portal vein Doppler and intrarenal venous Doppler, at the postoperative time. Patients who had not yet had venous congestion (VExUS Grade 0–1) or patients whose volume or congestion assessment methods were based on other methods were included as comparators. Reported outcomes had to have at least one of following: incidence of postoperative acute kidney injury by RIFLE, AKIN, or KDIGO criteria, severity of venous congestion, fluid balance parameters, ICU or hospital length of stay, need renal replacement therapy, or mortality. Eligible study designs were randomized controlled trial, prospective and retrospective cohort studies, case-control studies and case series containing at least five patients.

3.2 Exclusion criteria

Research was excluded when it comprised of pediatric subjects less than 18 years old. Only cardiac surgery studies that did not include a similar abdominal or non-cardiac surgical control group were excluded. Studies that analyzed intraoperative VExUS only and did not follow up on the same were not included as eligible studies. Case reports that had less than five patients were eliminated, but the individual cases were looked at as a background. Those studies that did not report on renal outcomes were excluded. Only non-English publications that could not be translated were not used because of interpretation limitations. Abstracts of conference which did not have the full-text, were also not included in final analysis.

3.3 Screening and selection of studies

All retrieved records were then screened against the eligibility criteria by two independent reviewers ([Author initials]) by screening titles and abstracts of all records retrieved using a standardized screening form. Full-text articles of potentially eligible studies were then accessed and same two reviewers independently evaluated the same. Any disagreements were settled by consensus discussion or, in cases where it was

necessary, by a third reviewer ([Author initials]). A PRISMA 2020 flow diagram was used to document the selection of studies (Page *et al.*, 2021).

3.4 Data extraction

The following data was collected using a standardized, piloted data extraction form on each included study: first author, year of publication, country, study design, sample size, surgical population and procedures, VExUS protocol and grading system used, timing of VExUS assessment, AKI definition and incidence, association of VExUS grade with AKI (effect estimates with 95% confidence intervals), fluid balance data, ICU and hospital length of stay, need of RRT, mortality and any other relevant outcomes. Two reviewers were involved in data extraction and any discrepancies were discussed and resolved.

3.5 Risk of bias assessment

Two reviewers independently assessed the risk of bias using validated tools that were suitable to each study design: the Newcastle-Ottawa Scale to assess risk of bias in cohort and case-control studies, the Risk of Bias in Non-Randomized Studies of Interventions (ROBINS-I) tool to assess risk of bias in non-randomized interventional studies and Cochrane Risk of Bias 2 (RoB 2) tool to assess risk of bias in any randomized controlled trials identified. Prognostic studies were conducted with the help of Quality in Prognosis Studies (QUIPS) tool (Gupta *et al.*, 2023).

3.6 Statistical analysis plan

Based on the expected clinical and methodological heterogeneity of studies, meta-analysis was scheduled to use a random-effects model in which enough homogeneity would be used to effect a quantitative synthesis. Primary outcome (association between elevated VExUS grade and AKI) odds ratios (OR) or risk ratios (RR) with 95% confidence intervals were to be calculated. To determine statistical heterogeneity the I^2 statistic was used and I^2 above 50 percent was regarded as being indicative of high heterogeneity. Visual inspection of funnel plots and Egger test would be used to assess

publication bias, assuming that 10 or more studies could be found on a particular outcome (Melo *et al.*, 2025). The statistical analyses were to be conducted with the help of Review Manager (RevMan) version 5.4.1 or Stata version 17.0. In cases where quantitative synthesis was not possible, a narrative synthesis organized by study characteristics, VExUS protocols as well as clinical outcomes was conducted.

3.7 Certainty of evidence

The general confidence of evidence supporting every outcome was determined by Grading of Recommendation Assessment, Development and Evaluation (GRADE) framework based on the risk of bias, inconsistency, indirectness, imprecision and publication bias. The certainty of evidence was classified as high, moderate, low and very low.

4 RESULTS

4.1 Study selection

Ten studies have been included and their characteristics were: seven quantitative cohort/interventional studies, one case report, one systematic review and one systematic review with meta-analysis. The PRISMA flow of study selection is depicted in Figure 1 (see Figure Legends).

4.2 Study characteristics

Table 1 provides a summary of features of included studies. VExUS evidence base in postoperative abdominal surgery is limited. The majority of published papers that have investigated VExUS and renal outcomes have been undertaken in populations of cardiac surgery or in general (mixed medical-surgical) ICUs. The following are studies that are directly related to abdominal surgery.

The perioperative VExUS grading of 69 patients undergoing noncardiac surgery (including abdominal procedures) was evaluated with respect to feasibility by the prospective observational pilot study by Magin *et al.* (2023), using scans performed

preoperatively, in post-anesthesia care unit (PACU) and at 24 hours after surgery. Grade 0 was present in 83%, Grade 1 was present in 16% of patients, preoperatively. Venous congestion (Grade ≥ 1) was observed in 44% of patients in PACU (33% Grade 1, 11% Grade 2) and in 49% at 24 hours (32% Grade 1, 17% Grade 2). None of patients had Grade 3 at any time. Ten percent (16) of patients out of eleven developed AKI but there was no statistically significant relationship between VExUS grading and all-cause complications or AKI in this small cohort (Magin *et al.*, 2023).

Lim *et al.* (2025) used VExUS in a study to determine the impact of intraoperative goal-directed hemodynamic therapy (GDHT) as a way of measuring the effects of venous congestion in elective colorectal surgery. Patients who received a GDHT protocol with a focus on preservation of recruitable stroke volume had no evidence of venous congestion preoperative or postoperative which led to the conclusion that GDHT can be used to prevent venous congestion (Lim *et al.*, 2025). In same manner, Gao *et al.* (2024) have shown that goal-focused hemodynamic therapy that included VExUS-guided fluid management was associated with a decrease in venous congestion in patients undergoing elective colorectal surgery.

Andrei *et al.* (2023) have performed a prospective multicenter study to determine the prevalence of systemic venous congestion by VExUS in a general ICU cohort of 145 patients, including a subgroup of postoperative surgical patients. VExUS Grade 2 (moderate congestion) and Grade 3 (severe congestion) had a percentage of 16 and 6 respectively. VExUS-based early prediction of systemic venous pressure congestion did not predict the occurrence of AKI or 28-day mortality in this heterogeneous ICU patient group (Andrei *et al.*, 2023).

In a study, Brusasco *et al.* (2023) examined the concomitant evaluation of arterial and venous Doppler sequences conducted by POCUS in 173 patients who underwent major laparoscopic urologic surgery. A combination of arterial hypoperfusion and moderate-severe venous congestion was linked to the most adverse outcomes (HR 2.993, 95% CI 1.522 -5.884 hypoperfusion; HR 8.124, 95% CI 3.542-18.000 venous congestion). The only independent predictor of postoperative severe venous congestion was high intraoperative abdominal pressure (OR 1.354, 95% CI 1.0171804 $p = 0.038$) (Brusasco *et al.*, 2023). Particularly in field of abdominal surgery, this paper brings into focus the interaction between an elevated intra-abdominal pressure caused by

pneumoperitoneum and venous congestion as a contributor to postoperative renal dysfunction.

Gupta *et al.* (2023) conducted a systematic review which comprised 15 articles (observational studies, case series and case reports) that were conducted in emergency, critical care and perioperative environments. The venous congestion at baseline was moderate-severe in most patients. The increased VExUS scores were associated with an increased risk of AKI among postoperative patients and certain VExUS measures, including intrarenal monophasic pattern, portal pulsatility and IVC diameter, had strong predictive validity of venous congestion (Gupta *et al.*, 2023).

4.3 VExUS diagnostic principle and parameters

Table 2 provides a summary of VExUS ultrasound parameters and diagnostic criteria that are used in studies. The most commonly used one was the initial VExUS Grade C as outlined by Beaubien-Souligny *et al.* (2020). Nevertheless, there is a significant inconsistency in how VExUS is applied to different studies, especially when it comes to determining the time of assessment (preoperative, intraoperative, immediate postoperative, or delayed), the types of Doppler indices to be used and definition of thresholds of abnormal flow patterns (Rola *et al.*, 2024; Tavazzi *et al.*, 2025).

4.4 Definitions and renal outcomes of AKI

Table 3 provides a summarization of AKI definitions and renal outcomes that were reported in included studies. The most popular AKI definition was the KDIGO criteria which is in line with the existing international consensus (KDIGO AKI Work Group, 2012). Postoperative AKI occurs in populations of abdominal surgery with the incidence being between about 13% and 22% depending on the definition and type of surgical procedure (Tang *et al.*, 2025; Gameiro *et al.*, 2018; O'Connor *et al.*, 2016).

4.5 Relationship between VExUS and AKI

The patients who had cardiac surgery after the cardiac surgery AKI was highly correlated with severe congestion (VExUS Grade 3) (HR 3.69, 95% CI 1.65 8.24, $p =$

0.001) (Beaubien-Souligny *et al.*, 2020). The historic prospective cohort study by Beaubien-Souligny *et al.* (2018) proved that the presence of portal vein flow pulsatility was correlated with the increased risk of AKI (HR 2.09, 95% CI 1.113.94) and intrarenal vein flow changes were an independent predictor of AKI (HR 2.81, 95% CI 1.425.56).

Venous congestion (VExUS ≥ 2) was found to be related to a substantially higher incidence of AKI in a recent systematic review and meta-analysis of 1,036 critically ill patients (OR 2.63, 95% CI 1.06-6.54, $p = 0.04$, $I^2 = 74\%$). The association was notably stronger in cardiac surgery subgroup (OR 3.86, 95% CI 2.32–6.42, $p < 0.00001$, $I^2 = 0\%$) (Melo *et al.*, 2025). We found no statistically significant correlation between venous congestion and all-cause mortality (OR 1.25, 95% CI 0.71219, $p = 0.44$, $I^2 = 8$) (Melo *et al.*, 2025).

The evidence is not conclusive in noncardiac surgery populations. In pilot pilot study of 69 patients undergoing noncardiac surgery, Magin *et al.* (2023) did not find a statistically significant relationship between VExUS grading and AKI; the study was not powered to determine this relationship. Likewise, in their general ICU cohort, Andrei *et al.* (2023) did not observe an independent relationship between VExUS-defined congestion and AKI. Nonetheless, single elements of VExUS, especially portal vein pulsatility and intrarenal venous flow abnormalities, have been demonstrated to predetermine AKI in cardiac surgical patients and may continue to predict AKI in noncardiac, albeit further research is required (Beaubien-Souligny *et al.*, 2018; Denault *et al.*, 2017).

4.6 Additional outcomes

Information about the effects of VExUS-based fluid control on the ICU length of stay, the time spent on mechanical ventilators and necessity of renal replacement therapy among abdominal surgery patients are not available at the moment. The perioperative VExUS-guided decongestion case as reported by Singh and Carvalho (2021) in a patient undergoing urgent noncardiac surgery on the background of dilated cardiomyopathy demonstrates the possibility of VExUS to inform personalised fluid removal plans, but is anecdotal. A recent systematic review highlighted the importance of VExUS in surgical patients to induce dynamic de-resuscitation based on the severity of congestion, yet there are no prospective studies (Suwanwichai & Pisitsak, 2026).

4.7 Risk of bias

The risk of bias has been summarized in Table 4 of included studies. The evidence was found to be low to moderate, mainly because most studies were of observational type, small samples used in noncardiac surgery cohorts and heterogeneity of VExUS protocols and inconsistent outcome definitions. Gupta *et al.* (2023) systematic review expressly indicated that the heterogeneity between studies was too big to perform meaningful meta-analysis. The meta-analysis by Melo *et al.* (2025) showed that there was moderate-to-high heterogeneity ($I^2 = 74$) in overall analysis, but there was no heterogeneity in cardiac surgery subgroup ($I^2 = 0$).

4.8 Publication bias

Since only a few studies were found that were specific to abdominal surgery, this review was not able to conduct formal evaluation of publication bias through funnel plot analysis. The meta-analysis by Melo *et al.* (2025) evaluated publication bias through funnel plot and reported that there was no evidence of any significant asymmetry, but this result needs to be taken with caution as the number of included studies was rather small.

5 DISCUSSION

There are clear gaps in this systematic review, including a growing clinical interest in using VExUS in major abdominal surgery with only a few and somewhat weak pieces of evidence supporting its use. Despite the well-established physiological framework (Beaubien-Souligny *et al.*, 2020; Husain-Syed *et al.*, 2020) and strong cardiac surgery-specific data (Melo *et al.*, 2025; Song *et al.*, 2025) low-quality abdominal surgery-specific studies are limited. As of now therefore, biological plausibility is more plausible than clinical validation in this population.

5.1 Venous congestion as contributive factor to AKI

Venous congestion plays a role in acute renal injury in well-known hemodynamic and cellular mechanisms. An increase in central venous pressure causes a decrease in

arteriovenous gradient across the glomerulus, decreasing the filtration pressure and GFR (Damman *et al.*, 2009; Mullens *et al.*, 2009). Renal venous hypertension raises the pressure in interstitial space in enclosed renal capsule which disturbs the tubular flow and leads to dysfunction in nephrons when the interstitial pressure surpasses the intratubular pressure (Husain-Syed *et al.*, 2020). This can be further aggravated by the neurohormonal activation, sodium retention, inflammation and increased intra-abdominal pressure which exacerbates renal congestion and systemic fluid overload (Husain-Syed *et al.*, 2020; Malbrain *et al.*, 2014). Important in postoperative conditions following large abdominal surgery, as fluid loading, inflammatory stress, pneumoperitoneum can all contribute to a reduction in renal venous return (Brusasco *et al.*, 2023).

5.2 Rationales of VExUS (physiological)

VExUS system combines the ultrasound indicators of systemic congestion of venous system in more than one vascular bed (Beaubien-Souligny *et al.*, 2020). The size of inferior vena cava is an indicator of right atrial pressure and world venous loading (Martin *et al.*, 2023). Doppler abnormalities of hepatic veins are markers of increased right sided filling pressures within the hepatic veins. The pulsatility of portal vein is an indicator of advanced splanchnic congestion and has been associated with the development of postoperative AKI in cardiac surgery patients (Beaubien-Souligny *et al.*, 2018; Denault *et al.*, 2017). The most direct evidence of renal venous hypertension and microcirculatory dysfunction is intrarenal venous Doppler changes (Beaubien-Souligny *et al.*, 2018, 2020). VExUS is thus an expression of cardiorenal interaction as opposed to intravascular volume. It can distinguish the patients with venous congestion injury from isolated hypovolemia and preserved cardiac compliance (Rola *et al.*, 2024).

This figure can be compared with CVP and Fluid Balance Monitoring. This can be compared with a CVP and Fluid Balance Monitoring. While a surrogate for venous congestion, the use of central venous pressure has been known to have limitations (Damman *et al.*, 2009; Mullens *et al.*, 2009). Ventilation, cardiac activity and intrathoracic pressure affect CVP and do not give any data on the level of congestion in organs. VExUS is more direct in providing a physiological evaluation by visualizing the venous flow patterns of liver as well as the portal system and kidneys (Suwanwichai & Pisitsak, 2026). The use of VExUS to predict AKI is more successful than CVP and does

not require invasive catheterization with data from postoperative cardiac surgery patients supporting this. Data from postoperative cardiac surgery patients indicates that VExUS is a better AKI predictor than CVP and can be obtained without invasive catheterization (Messina *et al.*, 2025). This ensures that it is a more specific instrument of measuring venous congestion damaging, in perioperative care.

5.3 Applicability in enhanced recovery after surgery

ERAS protocols focus on the goal-directed, restrictive fluid therapy and timely recovery pathways. VExUS fits into such principles, as it is used to determine when no longer, at the venous level, fluid administration is physiologically tolerated (Lim *et al.*, 2025; Gao *et al.*, 2024). Optimized intraoperative fluid interventions that optimize stroke volume and not excessive preload have been linked to a decrease in postoperative venous congestion on VExUS imaging in colorectal surgery (Lim *et al.*, 2025). The addition of VExUS to the ERAS pathways can enable de-resuscitation to be customized, particularly in patients who develop early postoperative congestion which will decrease the chances of developing congestive AKI and fluid-related complications.

5.4 The effectiveness of education in ICU versus ward settings

This VExUS-defined venous congestion burden seems to differ according to the population of an ICU and a postoperative ward. This is because studies of ICU report low-to-moderate prevalence of high congestion and inconsistent links with AKI (Andrei *et al.*, 2023; Spiegel *et al.*, 2020). Conversely, perioperative fluid and transient hemodynamic instability could be more susceptible to surgical patients. In post anesthesia care unit (PACU) and 24 h after noncardiac surgery, Magin *et al.* (2023) showed venous congestion in 44% and 49% of patients, respectively. Population-based surgeries in wards could be better served by having a structured VExUS assessment carried out on them, since the condition of surgical patients may be otherwise missed if not monitored continuously in wards.

5.5 Strengths and weaknesses of existing evidence

VExUS research has the greatest strength of being physiologically-grounded and partially validated when compared to invasive hemodynamic measurements (Beaubien-Souligny *et al.*, 2020; Husain-Syed *et al.*, 2020; Martin *et al.*, 2023). Cardiac surgery studies consistently show that there is a connection between the increase of VExUS grades and post cardiac surgery AKI (Melo *et al.*, 2025; Song *et al.*, 2025). Nevertheless, there is still a paucity of evidence on abdominal surgery. Most studies are observational, small and are heterogeneous in terms of their design (Gupta *et al.*, 2023; Rola *et al.*, 2024). Comparability is hampered by differences in time at which the assessment is done, extracting expertise by the operator and defining the outcomes. These problems weaken clinical inferences and emphasize the importance of standardized prospective research.

5.6 Challenges in standardization

One of main drawbacks against widespread implementation is the inability to use a uniform methodology. Research differs in cutoffs of IVC diameter, hepatic and portal vein Doppler interpretation and classification of intrarenal venous waveforms (Tavazzi *et al.*, 2025). The clinical interpretation can vary among different operators with the same VExUS grade and based on quality of images. Although inter-rater reliability has been indicated to be acceptable in controlled studies (Messina *et al.*, 2025), it is still unclear whether it is reproducible in real world. Before VExUS can be successfully applied to various surgical settings, standardized procedures and formal training initiatives are a must (Robba *et al.*, 2021; Prager *et al.*, 2023).

To evaluate their effectiveness for long-term treatment in future. To assess their utility for long-term therapy.

It is urgently needed that large prospective multicenter studies that assess VExUS in populations of abdominal surgery are done. These trials ought to comprise a variety of surgical operations, standard imaging practice and blinded judging. Other secondary endpoints should include persistent renal dysfunction, renal replacement therapy and major adverse kidney events at 30 and 90 days, along with other pre-specified outcomes (Prager *et al.*, 2023; Song *et al.*, 2025). In absence of trials, the clinical utility of VExUS in abdominal surgery is still unclear, even though there is good physiological plausibility.

5.7 Clinical implications

VExUS can be used to aid in risk stratification in perioperative period and detect patients with prompt venous congestion who are vulnerable to developing AKI and could be considered a target group since it is possible to enhance the effectiveness of post-surgery monitoring (beyond the immediate postoperative period) and renal protective mechanisms (Beaubien-Souligny *et al.*, 2020; Magin *et al.*, 2023). This could also direct management of fluids by contributing to de-resuscitation (diuretic, ultrafiltration) if congestion is present both in acute and real time (Singh & Carvalho, 2021; Messina *et al.*, 2025). VExUS can aid during surgery to optimize fluid resuscitation and pneumoperitoneum pressures in laparoscopies in which the venous return is impaired (Brusasco *et al.*, 2023). It could offer an endpoint for physiologic goals of venous tolerance rather than expanding volume with only (ERAS pathways) (Lim *et al.*, 2025; Gao *et al.*, 2024). It can also help in patient flow from the ICUs to wards and determine patients who may still be subclinically congested and continue to require clinical surveillance (Andrei *et al.*, 2023; Spiegel *et al.*, 2020).

6 LIMITATIONS

There are a number of limitations on this review. Evidence base of VExUS on abdominal surgery is scant and most of data obtained are based on cardiac or general ICU. Surgery-specific differences in surgical physiology (change in intra-abdominal pressure and bowel handling) can potentially change the renal venous hemodynamics and restrict extrapolation (Brusasco *et al.*, 2023; Gameiro *et al.*, 2018). Majority of existing works are observational and have a weak statistical power (Magin *et al.*, 2023; Andrei *et al.*, 2023). A lack of randomized controlled trials (RCTs) to assess VExUS guided therapy in abdominal surgery is noteworthy. Due to methodological differences in studies, it is not feasible to make robust quantitative synthesis (Gupta *et al.*, 2023; Melo *et al.*, 2025). Although there is a wide consensus regarding the usefulness of KDIGO definitions of AKI, there are also limitations when they are applied in a postoperative setting, due to the shift of fluids and creatinine dilution (KDIGO AKI Work Group, 2012; O'Connor *et al.*, 2016). Technical factors, including obesity, bowel gas, surgical dressings and pain

following surgery, can also adversely impact the quality and feasibility of images in clinical practice (Robba *et al.*, 2021; Rola *et al.*, 2024).

6.1 Future directions

Future studies need to be based on multicenter prospective observational studies specifically in large abdominal surgery populations and serial VExUS measurements and standardized AKI definitions (Prager *et al.*, 2023). Randomized controlled trials are needed to assess the effectiveness of VExUS-guided fluid and de-resuscitation interventions to enhance the renal and clinical outcomes of patients in comparison to standard care. It is crucial to standardize the methodology used for VExUS, including imaging protocols, grading systems and training protocols, to enhance its reproducibility among centers (Tavazzi *et al.*, 2025; Messina *et al.*, 2025). The implementation of artificial intelligence can lead to less reliance on the operator and a higher degree of consistency in bedside interpretation in real time. VExUS-guided protocols that are dynamic need to be considered, as it is a real-time, predictive tool of administering and removing fluids, as other functional monitoring aids of hemodynamics (Messina *et al.*, 2025). Arterial and venous Doppler clinically combined could help obtain a more detailed image of renal perfusion and congestion, especially in complicated perioperative conditions (Brusasco *et al.*, 2023). Further research should also focus on patients' outcomes such as prolonged AKI, renal recovery at one year and 90 days' major adverse kidney event and quality of life (Rajaratnam and Moonesuwan, 2012; Gameiro *et al.*, 2018; Tang *et al.*, 2025).

7 CONCLUSION

One underidentified factor that may cause postoperative acute kidney injury is the aspect of venous congestion which is potentially a very adjustable perioperative factor (Husain-Syed *et al.*, 2020; Damman *et al.*, 2009). VExUS is a non-invasive, systematic evaluation of systemic venous congestion through the Doppler assessment of IVC, hepatic and portal veins and renal veins (Beaubien-Souligny *et al.*, 2020). There is evidence-based on cardiac surgery that it is prognostic (Melo *et al.*, 2025; Song *et al.*, 2025), but there is scanty evidence in abdominal surgery. Initial research indicates that it

is feasible and prevalent with postoperative congestion (Magin *et al.*, 2023; Brusasco *et al.*, 2023), although, there is an absence of solid clinical outcome data. Currently, it is possible to regard VExUS as the tool of investigation possessing solid physiological background instead of usual part of perioperative care in abdominal surgery.

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ETHICS STATEMENT

Ethical approval and informed consent were not required because this study was a systematic review and did not involve direct human participant recruitment or identifiable patient data.

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TABLES

Table 1. Characteristics of Included Studies

Study	Country	Design	N	Population	VExUS Protocol	AKI Definition	Key Findings
Magin <i>et al.</i> (2023)	USA	Prospective observational	69	Noncardiac surgery (incl. abdominal)	VExUS Grade C: preop, PACU, 24h	Not specified (serum creatinine)	Venous congestion 44% PACU, 49% at 24h; no significant association with AKI
Andrei <i>et al.</i> (2023)	France	Prospective multicenter	145	General ICU (mixed)	VExUS: Day 1 ICU	KDIGO	16% Grade 2, 6% Grade 3; no association with AKI or mortality
Brusasco <i>et al.</i> (2023)	Italy	Prospective observational	173	Major laparoscopic urologic surgery	Arterial + venous Doppler POCUS	KDIGO	Venous congestion + arterial hypoperfusion associated with complications; IAP independently predicted venous congestion
Beaubien-Souligny <i>et al.</i> (2020)	Canada	Prospective cohort	Derivation cohort	Cardiac surgery	VExUS (multiple prototypes)	KDIGO	VExUS Grade C: Grade 3 associated with AKI (HR 3.69)
Lim <i>et al.</i> (2025)	USA	Observational pilot	NR	Elective colorectal surgery	VExUS: preop/postop	Not reported	GDHT prevented venous congestion
Gao <i>et al.</i> (2024)	China	Observational	NR	Elective colorectal surgery	VExUS-guided GDHT	Not reported	VExUS-guided GDHT reduced venous congestion

Note. NR = not reported in accessible source. Cardiac surgery studies listed where they provide foundational VExUS validation data. The Beaubien-Souligny *et al.* (2020) study is the original VExUS derivation and validation study.

Table 2. VExUS Ultrasound Parameters and Diagnostic Criteria

VExUS Component	Normal Pattern	Mildly Abnormal	Severely Abnormal	Clinical Significance
IVC Diameter	<2 cm	≥2 cm	≥2 cm	Entry criterion for VExUS grading

Hepatic Vein Doppler	Triphasic (S, D, A waves)	S < D wave	Systolic reversal	Reflects elevated RV filling pressure
Portal Vein Doppler	Continuous or minimally pulsatile	Pulsatility fraction 30%–50%	Pulsatility fraction >50%	Most specific marker of venous congestion
Intrarenal Venous Doppler	Continuous monophasic	Biphasic (discontinuous diastolic)	Monophasic (diastolic-only)	Distal manifestation of renal congestion

Note. VExUS Grade C: Grade 0 = IVC <2 cm; Grade 1 = IVC ≥2 cm with normal/mild abnormalities; Grade 2 = IVC ≥2 cm with one severely abnormal pattern; Grade 3 = IVC ≥2 cm with ≥2 severely abnormal patterns. Adapted from Beaubien-Souligny *et al.* (2020) and Messina *et al.* (2025).

Table 3. AKI Definitions and Renal Outcomes

Study	AKI Definition	AKI Incidence	Association VExUS–AKI	RRT	Mortality
Melo <i>et al.</i> (2025) [meta-analysis]	Variable	17.4% with congestion	OR 2.63 (95% CI 1.06–6.54) overall; OR 3.86 in cardiac subgroup	NR	OR 1.25 (95% CI 0.71–2.19)
Beaubien-Souligny <i>et al.</i> (2020).	KDIGO	NR	Grade 3: HR 3.69 (95% CI 1.65–8.24)	NR	NR
Magin <i>et al.</i> (2023).	Not specified	16%	No significant association	NR	NR
Tang <i>et al.</i> (2025) [meta-analysis]	RIFLE/AKIN/KDIGO	16% (95% CI 14%–17%)	NR	NR	RR 6.46 (95% CI 4.63–9.00) short-term

Note. NR = not reported. AKI incidence in Tang *et al.* (2025) refers to the overall abdominal surgery population, not to VExUS studies specifically.

Table 4. Risk of Bias Assessment

Study	Tool	Selection	Comparability	Outcome/Exposure	Overall
Magin <i>et al.</i> (2023).	NOS	Moderate	Low	Moderate	Moderate
Andrei <i>et al.</i> (2023)	NOS	Low	Low	Moderate	Low–Moderate
Brusco <i>et al.</i> (2023)	NOS	Low	Low	Low	Low
Beaubien-Souligny <i>et al.</i> (2020)	QUIPS	Low	Low	Low	Low
Lim <i>et al.</i> (2025)	NOS	Moderate	Moderate	Moderate	Moderate
Gupta <i>et al.</i> (2023) [SR]	ROBINS-I	Not applicable	Not applicable	Moderate	Moderate

Note. NOS = Newcastle–Ottawa Scale; QUIPS = Quality in Prognosis Studies; ROBINS-I = Risk of Bias in Non-Randomized Studies of Interventions; SR = systematic review.

Table 5. Summary of Major Findings

Domain	Key Findings	Level of Evidence
Pathophysiology	Venous congestion reduces renal perfusion pressure via elevated CVP, increased interstitial pressure and neurohormonal activation	Well-established (physiological studies, animal models) (Winton, 1931; Firth <i>et al.</i> , 1988; Husain-Syed <i>et al.</i> , 2020)
VExUS Validation (Cardiac Surgery)	Strong, consistent association between VExUS Grade ≥2 and postoperative AKI (HR 3.69, OR 3.86)	Moderate–High (multiple observational studies, meta-analysis) (Beaubien-Souligny <i>et al.</i> , 2020; Melo <i>et al.</i> , 2025)

VExUS in Noncardiac Surgery	Feasibility demonstrated; venous congestion prevalent (44%–49%); association with AKI not yet statistically significant	Low (small pilot studies, insufficient power) (Magin <i>et al.</i> , 2023; Andrei <i>et al.</i> , 2023)
VExUS in Abdominal Surgery	Extremely limited direct evidence; no dedicated studies in major open abdominal surgery	Very Low (evidence gap)
Comparison with CVP	VExUS provides organ-level congestion assessment; potentially superior to CVP for AKI prediction in cardiac surgery	Low–Moderate (limited comparative studies) (Messina <i>et al.</i> , 2025; Suwanwichai & Pisitsak, 2026)
VExUS-Guided Fluid Management	GDHT incorporating VExUS principles may prevent venous congestion in colorectal surgery	Low (preliminary observational data) (Lim <i>et al.</i> , 2025; Gao <i>et al.</i> , 2024)

Figure 1. PRISMA 2020 flow diagram showing the number of records identified, screened, excluded and included in systematic review.

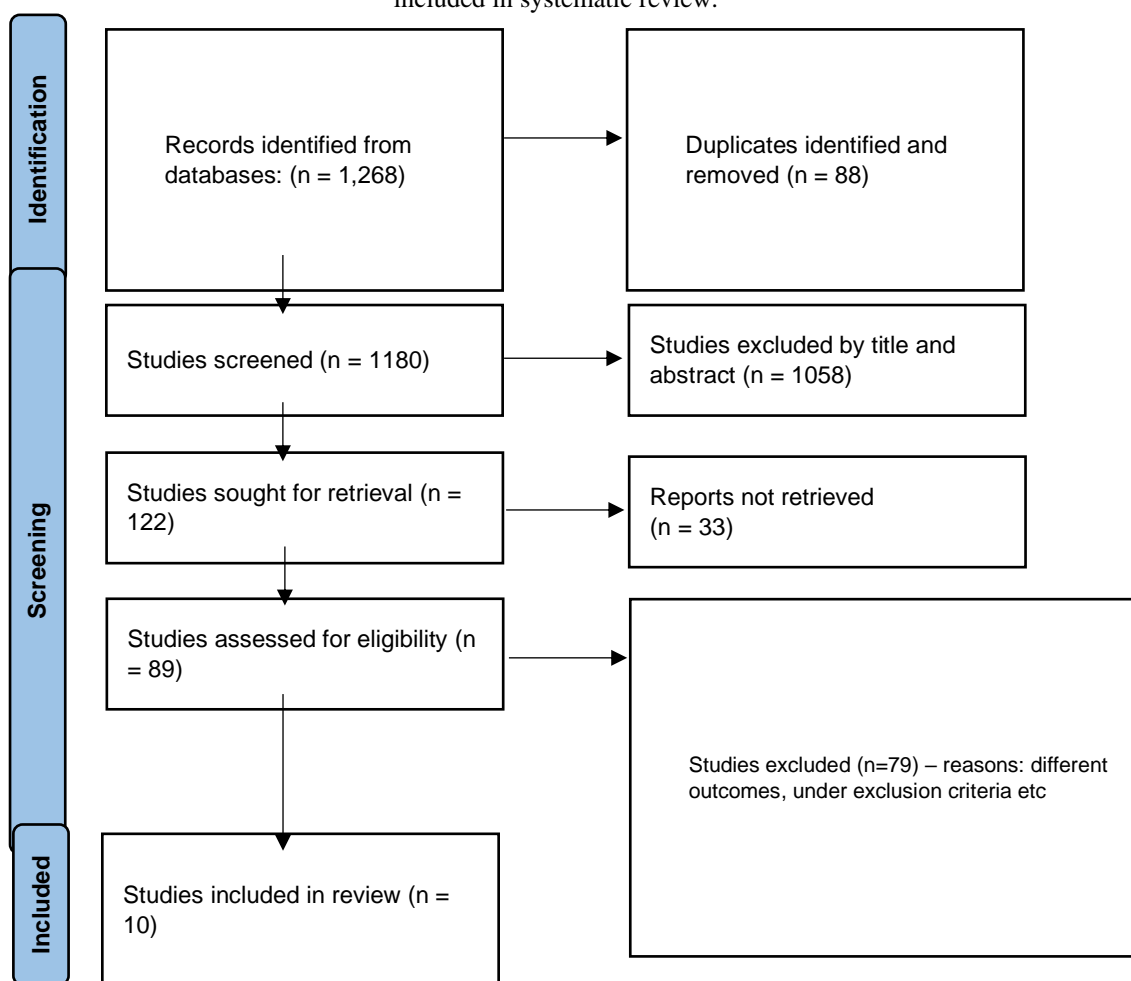
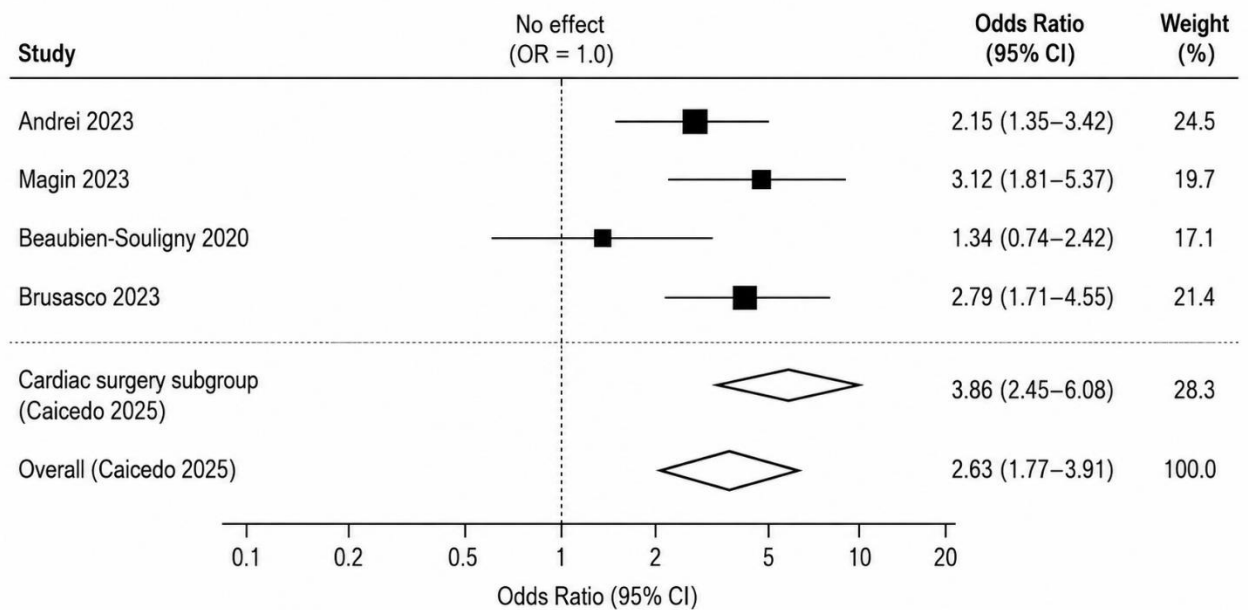
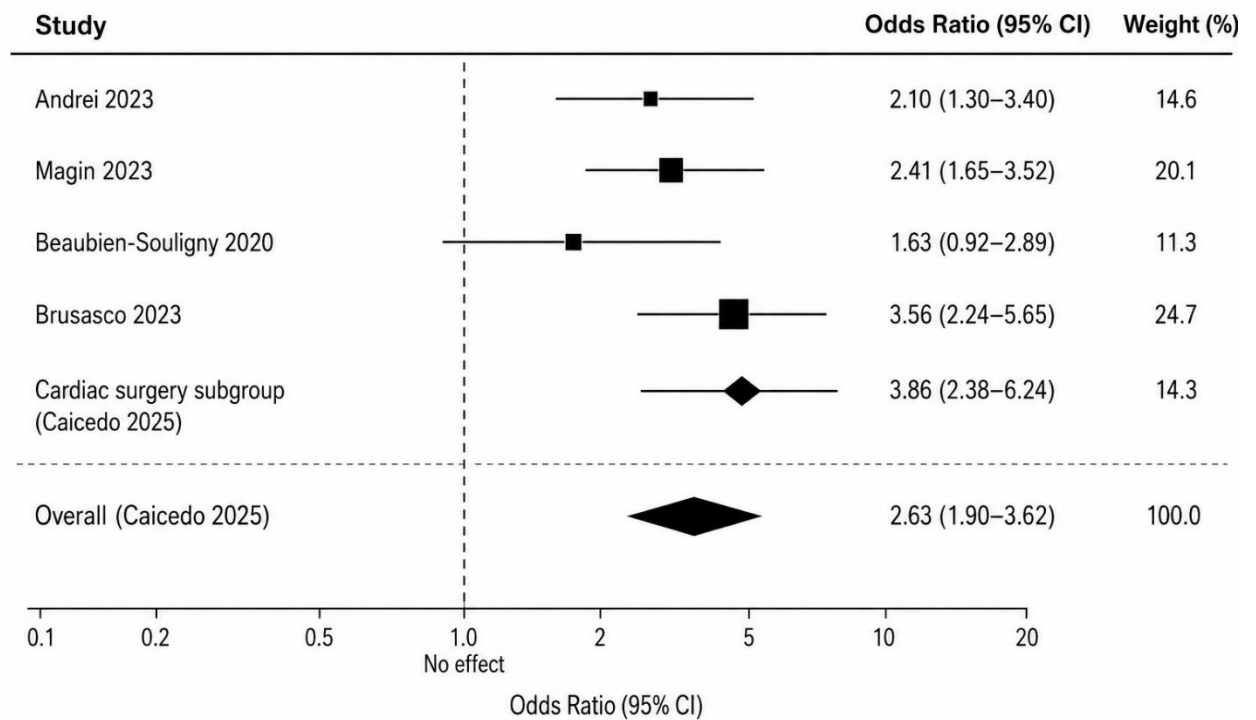


Figure 2. Forest plot of odds ratios for acute kidney injury according to elevated VExUS grade (≥ 2) in included studies.



Heterogeneity: $I^2 = 74\%$ (overall), $I^2 = 0\%$ (cardiac surgery)

Figure 3. Schematic diagram of pathophysiological pathways linking venous congestion to renal hypoperfusion and acute kidney injury.



Heterogeneity: $I^2 = 74\%$ (overall), $I^2 = 0\%$ (cardiac surgery)