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Assessment of fluid status and responsiveness in acute right ventricular failure – a narrative review

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Abstract

Background. Acute right ventricular failure (ARVF) is a life-threatening syndrome causing systemic congestion, low cardiac output, and possible hemodynamic collapse. Fluid therapy is a key intervention, but the failing right ventricle is highly sensitive to both insufficient preload and fluid overload, making accurate assessment of volume status and fluid responsiveness crucial.

Aim. To review the evidence on fluid therapy assessment in ARVF, focusing on central venous pressure (CVP), point-of-care ultrasonography (POCUS), and venous excess ultrasound (VExUS).

Material and methods. A narrative review of publications from 2016–2026 (with selected fundamental older studies) covering ARVF, fluid therapy, fluid responsiveness, CVP, POCUS, IVC assessment, and VExUS. Guidelines, RCTs, meta-analyses, observational studies, and reviews in English or Polish were considered.

Results. Fluid administration in ARVF should be cautious, as excessive preload may worsen RV performance, tricuspid regurgitation, venous congestion, and instability. Guidelines emphasize clinical assessment, CVP, and invasive monitoring but offer limited guidance on fluid responsiveness. CVP is widely used yet limited and should not guide therapy alone. POCUS and VExUS are promising adjuncts for assessing congestion and right-sided hemodynamics, but current evidence does not support them as standalone methods; their value is greatest when integrated with clinical and hemodynamic findings and RV function. Evidence on optimal fluid type is scarce, though indirect data suggest possible benefit of balanced crystalloids over normal saline.

Conclusions. Fluid therapy in ARVF requires individualized, closely monitored decisions. No single method reliably guides it. CVP, POCUS, and VExUS provide complementary information interpreted within the clinical context. In uncertain cases, a cautious fluid challenge under close monitoring may be preferable to empiric liberal fluid administration.

Key words: acute right ventricular failure; fluid responsiveness; VExUS; POCUS; CVP

1. Introduction

Acute right ventricular failure is an acute condition consisting of RV dysfunction with systemic congestion and possible hemodynamic decompensation in the various forms with cardiogenic shock included (Giannakoulas et al., 2025; Harjola et al., 2016; Konstam et al., 2018). It is a serious syndrome whose mortality rate (when mechanical circulatory support is needed) reaches up to 70% (Manca et al., 2025). One of its most common causes is pulmonary embolism (Giannakoulas et al., 2025), a form of venous thromboembolism - third most frequently occurring circulatory syndrome after myocardial infarction and stroke (Konstantinides et al., 2020). The topic is therefore epidemiologically important. Fluid therapy is one of the elements of ARVF management (Harjola et al., 2016; Konstam et al., 2018). From the pathophysiological point of view volume loading in the course of this syndrome requires caution: because of the volume limitation of the RV, there is a real risk of overload and hemodynamic collapse (Luk et al., 2025). However, rational fluid administration can benefit patients, as it may increase cardiac output (Harjola et al., 2016; Konstam et al., 2018). The decision to initiate or discontinue fluid therapy seems to be crucial. Many tools to predict fluid responsiveness have been developed. The most recognizable in ARVF case seems to be central venous pressure measurement (Arrigo et al., 2024; Harjola et al., 2016; Konstam et al., 2018). However, its usage has limitations that draw attention to alternatives - especially imaging methods such as point-of-care ultrasonography (POCUS) and its component dedicated to systemic congestion assessing - venous excess ultrasound (VExUS). This narrative review focuses on available data and evidence on assessing volume status and fluid responsiveness by such methods.

2. Research materials and methods

2.1. Review design and search strategy

This study is a narrative literature review and is based on a comprehensive search and analysis of available scientific research on ARVF and fluid therapy in intensive care. The strategy involved searching for articles using combinations of the following terms with Boolean operators (AND/OR): acute right ventricular failure, fluid, volume, therapy, management, POCUS, VExUS, fluid responsiveness, IVC-CI, IVC, diameter, volume status, CVP. Several supplementary sources were also consulted to provide a more comprehensive overview of specific topics.

2.2. Inclusion and exclusion criteria

Inclusion criteria were as follows:

- Research published in years 2016-2026 (with a few exceptions justified by the significance of the research data for the advancement of knowledge in the field)
- Articles being guidelines of European or American scientific associations, randomized controlled trials, meta-analyses, case series, systematic and narrative reviews
- Articles in Polish or English

Exclusion criteria were as follows:

- Studies published before 2016 unless they provided fundamental data
- Case studies with insufficient clinical data
- Non-peer-reviewed articles.

2.3. Data collection and quality of evidence

After initial search and manual backward citation search, 31 studies were included. The data were narratively synthesized with particular emphasis on current pathophysiological models of acute right ventricular failure and their implications on fluid therapy, available methods of assessing fluid responsiveness and monitoring of fluid administration. Each study was analyzed in context of its design, sample size and methodology

3. Research results

3.1. Pathophysiology of right ventricular failure

Acute Right Ventricular Failure is an acute condition characterized by RV dysfunction leading to reduced cardiac output (CO), systemic congestion and hemodynamic decompensation including cardiogenic shock. While there are various causes of such syndrome, they act through one of three main mechanisms or their combination: volume overload, ventricular injury and pressure overload. This leads to uncoupling of RV contractility and pulmonary circulation resistance which is the main shared pathophysiological feature of different etiologies of RVF (Dodi & Jacobs, 2025; Giannakoulas et al., 2025).

Right ventricle and pulmonary artery (RV-PA) uncoupling occurs when RV cannot cope with load. The most suitable measure by which this concept is expressed is the ratio of RV to PA elastance (defined as the change in pressure per change in volume) - Ees/Ea. In normal conditions this ratio ranges from 1.5 to 2.0. ARVF develops when it drops to 0.7-1.0 (Giannakoulas et al., 2025).

RVF can develop in various ways. Myocardial injury impairs RV contractility and decreases its elastance. This occurs, for example in RV infarction. Pressure overload occurs when RV afterload rises, pulmonary vascular resistance increases together with PA elastance. The most common causes are pulmonary embolism, acute respiratory distress syndrome (ARDS) and pulmonary hypertension (cor pulmonale). Volume overload meaning excess of venous return (preload) is rarely the only cause of RVF, however, it can act in conjunction with other factors (Dodi & Jacobs, 2025; Giannakoulas et al., 2025; Harjola et al., 2016).

In regard to fluid management in ARVF, certain physiological features of RV - and their consequences under Ees/Ea uncoupling - are especially important. The RV has thinner wall and lower mass than LV, as it works against lower afterload - pulmonary circulation is low-resistance. It can, however, accommodate large changes in venous return (preload) (Giannakoulas et al., 2025). Venous return is defined by two variables - central venous pressure (CVP - downstream pressure for flow) and mean systemic filling pressure (Pmsf), the upstream driving pressure for that flow. Incidentally, from that reason CVP alone is not a sufficient marker of venous return, because it is only one of its determinants (Pierre-Grégoire, 2025; Si et al., 2026). In normal conditions, an increase in venous return (for example by fluid administration) enhances heart function and increases CO - the Frank-Starling effect. In Ees/Ea uncoupling RV easily becomes “volume-limited” meaning further increase in preload no longer enhances systolic contraction. It can occur due to increased PA pressure against which the RV works (increased afterload, pressure overload) which reduces the difference between end-diastolic and end-systolic volumes (stroke volume - SV). To compensate for high afterload, RV is in such cases very close to its maximum tolerable preload. When contractility of RV is impaired (e.g. in myocardial infarction) the afterload is relatively high for the RV’s current contractile state (Luk et al., 2025).

The volume limitation of RV in the state of Ees/Ea uncoupling is central to the question addressed in this review - the danger of fluid overload at hemodynamic decompensation. However, some patients may benefit from volume loading on the basis of the Frank-Starling effect. The volume management is therefore important and requires caution in patients with ARVF.

3.2. Assessing fluid status

Patients with ARVF may benefit from volume loading, however, this syndrome is often associated with RV overload and volume limitation, as mentioned before. Reaching the point when further fluid administration is not increasing CO but only worsening RV function with increasing wall tension, tricuspid regurgitation and other adverse effects, is real danger (Dodi & Jacobs, 2025; Giannakoulas et al., 2025; Harjola et al., 2016). There is, therefore, a need for an objective assessment of the validity of a fluid bolus, systemic congestion and fluid-responsiveness in patients with ARVF. In clinical practice, hemodynamic measurements such as CVP and right atrial pressure (RAP) are used for this purpose, as well as imaging studies like Point-of–Care Ultrasound (POCUS) and more advanced tools for assessing peripheral congestion such as Venous Excess Ultrasound (VExUS) (Dodi & Jacobs, 2025; Giannakoulas et al., 2025).

The most important papers on management of RVF are scientific statements of the American Heart Association (AHA) (Konstam et al., 2018) and European Society of Cardiology (Harjola et al., 2016). However, as shown further in the text, information on fluid (preload) management in these papers is quite limited, forcing us to extrapolate data from studies of similar pathophysiological syndromes or those in which RVF may develop (e.g., pulmonary embolism (Konstantinides et al., 2020) or heart failure secondary to cor pulmonale (Arrigo et al., 2024)), or from more general intensive care studies on fluid therapy (large RCTs or the Surviving Sepsis Campaign).

At this point it is important to address two issues. The first is to distinguish several fundamental fluid therapy concepts which are fluid status, volemia, congestion and fluid responsiveness. While volemia refers to the degree of vascular filling, congestion is an accumulation of blood in veins leading to increased pressure and organ dysfunction. Fluid status is a general term denoting whether patients need volume loading or fluid removal (Si et al., 2026). Fluid responsiveness on the other hand is a situation when fluid administration increases CO due to the Frank-Starling effect (Monnet et al., 2025). The second issue concerns fluid responsiveness itself. The main methods to assess it are dynamic tests like pulse pressure and stroke volume variations (PPV and SVV respectively) or passive leg raising (PLR). However, these methods have numerous limitations. In case of PPV and SVV one of such limitations is the possibility of false positive results in the course of RVF. PLR, on the other hand, requires CO measurement and tends to yield false-negative results in presence of intra-abdominal hypertension (Monnet et al., 2022) (in which imaging methods described below might be of particular value). For this reason, this section will focus on alternative methods of assessing fluid status or fluid responsiveness mentioned in various studies on ARVF.

Most studies relevant to preload management in ARVF suggest caution with fluid administration. Decision whether a patient requires fluid bolus or rather diuresis should be made after assessing fluid responsiveness and followed by close observation. In this context, the ESC and AHA statements on RVF mention clinical examination, CVP measurement and monitoring of filling pressures. A similar recommendation appears in the ESC statement on RVF secondary to an acute increase in afterload (Arrigo et al., 2024; Harjola et al., 2016; Konstam et al., 2018). ESC statement on ARVF management recommends fluid bolus (>200 mL over 15-30 min.) in patients with normal CVP and low arterial pressure (Harjola et al., 2016). ESC guidelines on pulmonary embolism (PE) specify fluid volume of less than 500 mL (Konstantinides et al., 2020). However, information on precise decision thresholds is rather limited, as is guidance on the range of methods for assessing fluid responsiveness. For example we find no information about POCUS or VExUS. Later in this article, we will take a closer look at these methods.

3.2.1 CVP

Central venous pressure is a widely used variable related to RV function. AHA statement notes that the simplest way to evaluate it is palpation of jugular vein for its pulse which can determine the presence or absence of elevated CVP in most cases (Konstam et al., 2018). It can be followed by hemodynamic monitoring with curve recording and pressure readings. Enlarged A waves (resulting from high right ventricular elastance) and V waves (resulting from high right atrial elastance) may indicate increased central venous pressure (CVP) and right ventricular overload (Giannakoulas et al., 2025; Konstam et al., 2018). The recognized CVP threshold above which patients are most likely to benefit from fluid removal is 8-12 mmHg. Similar values apply to right atrial pressure (RAP) (Dayer et al., 2023; Dodi & Jacobs, 2025; Konstam et al., 2018). CVP monitoring may also be helpful during fluid administration:

any sudden rise from baseline value (e.g. by 5 mmHg) suggests that further administration most likely will not increase CO (Giannakoulas et al., 2025).

However, CVP alone is not an ideal reflection of RV volume overload. A now-classic meta-analysis of 43 studies regarding fluid responsiveness of patients in ICU or operating room showed that no data support guiding fluid therapy on CVP alone (Marik & Cavallazzi, 2013). The analysis was based on studies reporting either a correlation coefficient or an area under the ROC curve (AUC). The summary AUC for studies done in ICU was 0.56 (95% confidence interval [CI] 0.52-0.60) and 0.56 (95% CI 0.54-0.58) for the operating room group. Summary correlation coefficient between the baseline CVP and change stroke volume index or cardiac index was 0.28 (95% CI 0.16-0.40) for the ICU patients and 0.11 (0.02-0.21) for operating-room patients. Therefore no significant correlations were found.

CVP monitoring may still be beneficial even though it is not suitable to guide fluid therapy on its own. A retrospective study conducted at Zhejiang University (China) examined the effect of CVP and CO on survival in circulatory shock. Patients' ($n = 134$) CVP and CO were monitored at baseline and 24 h after initiating treatment. Based on change in these parameters (baseline to 24 h point) they were assigned to one of four groups (higher CVP + higher CO; lower CVP + higher CO; lower CVP + lower CO; higher CVP + lower CO). The group with lower CVP and higher CO had higher 28-day survival rates than other groups (log-rank [Mantel-Cox] = 8.758, $p = 0.033$) (Su et al., 2019). However, research has its real limitations such as limited sample size and the pooling of different shock etiologies. In the context of this narrative review it has to be noted that this study does not apply to ARVF, so only indirect conclusions can be drawn.

CVP measurement alone seems to be not sufficient to make definitive decisions on fluid administration in ARVF, especially in the context of imaging methods described further in the text or more sophisticated methods of hemodynamic monitoring (e.g. cardiac output monitoring). This is reflected in the fact that both the ESC statement on ARVF management (Harjola et al., 2016) and ESC statement on RVF secondary to cor pulmonale (Arrigo et al., 2024) mention this variable only in conjunction with other methods. However, keeping CVP relatively low may be associated with better survival in shock so it remains a parameter worth measuring.

3.2.2 POCUS

Point-of-care ultrasound (POCUS) is a non-invasive imaging method that has been used in emergency departments (EDs) and ICUs for more than 20 years. POCUS has become a standard diagnostic tool in managing symptoms such as dyspnea, chest pain or suspected shock. Numerous algorithms have been developed over this time allowing rapid and reasonably reliable diagnosis of many syndromes frequently seen in emergency medicine (Naddaf et al., 2024; Núñez-Ramos et al., 2024). As POCUS is used in acute heart failure to assess systemic congestion (Naddaf et al., 2024) attempts to apply it to predicting fluid responsiveness or fluid therapy monitoring appear to be natural steps. POCUS consists of cardiac ultrasound, lung ultrasound (LUS), inferior vena cava ultrasound, internal jugular vein (IJV) ultrasound and venous Doppler. VExUS, which is discussed in this paper, can also be regarded as part of POCUS (Naddaf et al., 2024) in the broad sense, although it has been listed separately due to its specific purpose of assessing congestion.

The usefulness and effectiveness of POCUS in clinical practice are demonstrated by diagnostic algorithms for emergency conditions based on this method. A systematic review and meta-analysis on identifying the type of shock using POCUS demonstrated the high utility of this application (Yoshida et al., 2023). Twelve studies - prospective and retrospective trials, secondary analyses of RCT - reported the diagnostic accuracy of POCUS in adult patients (n =1,132) with undifferentiated shock. Sensitivity and specificity were 0.82 (95% CI 0.68-0.91) and 0.98 (95% CI 0.92-0.99) for obstructive shock, 0.78 (95% CI 0.56-0.91) and 0.96 (95% CI 0.92-0.99) for cardiogenic shock. For hypovolemic shock these values were 0.90 (95% CI 0.84-0.94) and 0.92 (95% CI 0.88-0.95) respectively and for distributive shock 0.79 (95% CI 0.71-0.85) and 0.96 (95% CI 0.91-0.98). Higher values for specificities suggest that POCUS is better at confirming the type of shock than at excluding it. AUC for each type of shock was approximately 0.95 and the positive likelihood ratios for each type were greater than 10. Obstructive shock deserves particular attention, with a positive likelihood ratio of 40 (95% CI 11-105). POCUS is also effective in diagnosing acute heart failure as shown by another, recent meta-analysis. The study included 15 trials investigating the diagnostic performance (expressed as sensitivity, specificity or diagnostic odds ratio) of lung, cardiac or IVC POCUS (or combinations) in diagnosing AHF. Combining LUS and cardiac ultrasound was associated with specificity of 96% (95% CI 93-98) and sensitivity of 78% (95% CI 68-89). Combining LUS, cardiac ultrasound and IVC ultrasound showed higher specificity of 99% (95% CI 96-100) but lower sensitivity of 54%, (95% CI 9-100). The latter value however, is inconclusive owing to its very wide confidence interval (Popat et al., 2026).

However, assessing fluid status and responsiveness with POCUS is a different matter. Scientific statements on ARVF do not mention such a method (Harjola et al., 2016; Konstam et al., 2018). The parameters used for this purpose are IJV and IVC collapsibility. A prospective observational study conducted in the ICU of Al Wakra and Al Khor hospitals (Qatar) compared these two methods for predicting CVP in patients (n = 58). Correlations between CVP and collapsibility index of IVC (IVC-CI) and IJV (IJV-CI) were checked in different head elevations. At 30° the correlation between CVP and IJV-CI was strongest (r = -0.583, p = 0.0001). Correlation between CVP and IVC-CI was also significant (r = -0.540, p = 0.0001) (Jassim et al., 2019). However, it is important to note that this study shows how well ultrasound parameters reflect CVP. They therefore share all the limitations of CVP itself. There are also some case reports describing successful fluid therapy guided by such measurements (Kumar et al., 2023, 2024). However, with regard to predicting fluid responsiveness by POCUS, larger studies have highlighted important limitations. Meta-analysis including 26 studies investigating IVC-CI and 5 studies investigating IVC diameter in relation to fluid responsiveness reported a pooled sensitivity, specificity and AUC 0.71 (95% CI 0.62-0.80), 0.75 (95% CI 0.64-0.85) and 0.71 (95% CI 0.46-0.83) respectively. The lower limit of 95% CI in case of AUC is especially interesting as it suggests the test may perform no better than a chance. The authors highlighted the extreme heterogeneity of the studies and concluded that these parameters do not appear to be a reliable method to predict fluid responsiveness (Orso et al., 2020). Another meta-analysis, this time comparing diameters of IVC, IJV, subclavian and femoral veins for predicting fluid responsiveness, suggested that the first was most reliable. The study analyzed 30 trials (1,719 patients) and showed pooled sensitivity and specificity for IVC diameter 0.75 (95% CI 0.68-0.80) and 0.83 (95% CI 0.79-0.86) respectively (Kim et al., 2021). This meta-analysis reached more favorable conclusions noting the superiority of IVC diameter over other investigated parameters; nonetheless its results seem to be consistent with those of Orso et al. (2020) in showing limited reliability of such tools in fluid responsiveness prediction. Moreover, none of these studies were specific to ARVF, and these methods are subject to limitations similar to those of VExUS described below.

3.2.3 VExUS

Venous Excess Ultrasound (VExUS) is a method of assessing systemic venous congestion using ultrasonography. Recently, it has emerged as a potentially very useful tool for patients with or at risk of fluid overload. Nevertheless, a good understanding of what this method entails and what it addresses can help prevent oversimplifications that might lead to errors. This may require combining VExUS with elements of POCUS (Pierre-Grégoire, 2025; Si et al., 2026).

VExUS relies on several measurements: maximal inferior vena cava (IVC) diameter, venous Doppler patterns of the hepatic, portal and renal veins. Originally, several VExUS scores (grading congestion from 0 to 3) were described as VExUS A-E. They relied on different combinations of abnormalities in measurements listed above (see: Table 1). However VExUS C score was associated with cardiac surgery-associated acute kidney injury (Beaubien-Souligny et al., 2020).

Table 1. Original VExUS scores grading venous congestion.

	VExUS A	VExUS B	VExUS C	VExUS D	VExUS E
Grade 0	IVC < 2 cm	IVC < 2 cm	IVC < 2 cm	-	-
Grade 1	IVC ⩾ 2 cm All flow patterns normal	IVC ⩾ 2 cm All flow patterns normal	IVC ⩾ 2cm All flow patterns normal or mild abnormalities	All flow patterns normal	All flow patterns normal or mild abnormalities
Grade 2	IVC > 2 cm Mild abnormality in at least one pattern	IVC > 2 cm Mild or severe abnormality in at least one pattern	IVC > 2 cm Severe abnormalities in at least one pattern	Mild or severe abnormality in at least one pattern	Severe abnormalities in at least one pattern
Grade 3	IVC > 2 cm Severe abnormalities	IVC > 2 cm Mild or severe	IVC > 2 cm Severe abnormalities in	Mild or severe abnormalities	Severe abnormalities in ⩾ 2

	in at least one pattern	abnormalities in ⩾ 2 patterns	⩾ 2 patterns	in ⩾ 2 patterns	patterns

Source: Beaubien-Souligny et al., 2020

Since then, various studies have sought to establish correlation between VExUS and organ dysfunction or other clinical outcomes. There is some evidence from a cohort study (n = 712) that VExUS is associated with 90-day rehospitalization in case of heart failure (Tang et al., 2026). A secondary analysis of a prospective observational cohort conducted in Tamil Nadu (India) suggested that this parameter is associated with RV-PA coupling. The study included 43 pediatric patients (age 1month -17 years old). The parameters that were measured were VExUS and tricuspid annular plane systolic excursion to pulmonary artery systolic pressure ratio (TAPSE/PASP) a measure of RV-PA coupling. All patients were admitted to ICU after cardiac surgery where a series of measurements was performed on postoperative days 1-3. In the hierarchical model, increasing VExUS worsened TAPSE/PASP. Compared with the VExUS 0 group, patients with VExUS 1 had a TAPSE/PASP lower by 0.05 (CI 0.03-0.08). Furthermore, the VExUS 2 group was associated with a decrease in TAPSE/PASP by 0.09 (95% CI 0.06-0.11), and for VExUS 3 this value was 0.13 (95% CI 0.11-0.16). Higher VExUS scores were associated with more severe RV-PA uncoupling expressed by TAPSE/PASP (Siuba et al., 2025). Although the study concerns RV uncoupling (which is characteristic of ARVF), the pediatric population and sample size are limitations. In the context of this review, this paper only confirms that VExUS reflects RV function. This is supported by another study, this time cross-sectional and performed in adults. Patients (n = 80) included into study were intubated and mechanically ventilated for 24-48h, during which several measurements, including VExUS, were performed. VExUS grading was negatively correlated with TAPSE ($r = -0.670$, $p < 0.001$) and tricuspid E-wave ($r = -0.648$, $p < 0.001$) indicating reduced right ventricular function. Interestingly, PASP was not correlated with VExUS at all ($r = 0.061$, $p = 0.593$) (Gao et al., 2025).

At this point, we should ask what is the actual benefit of VExUS in comparison to other methods described earlier? One clear disadvantage compared with, for example, CVP measurement is the greater difficulty of image acquisition, which also makes VExUS harder to repeat. It is, however, non-invasive and can detect congestion at the organ level at a low CVP (owing to intra-abdominal hypertension occurring - the so-called "waterfall phenomenon”) (Si et al., 2026). In the context of fluid management it is especially important not to equate VExUS score with RV volume overload as primary or any cause of its failure. Just as CVP is not a universal measurement for venous preload but only the downstream component of the gradient driving this flow (Pmsf - CVP gradient), VExUS score is the resultant of volume load and RV function (Pierre-Grégoire, 2025; Si et al., 2026). This is also confirmed by the studies cited earlier, which show a link between VExUS and various indicators of right ventricular function. However, this does not affect the usefulness of VExUS in making decisions regarding the fluid administration or removal in patients with ARVF. It should, however, be used in conjunction with other methods rather than on its own. One example of such an approach could be combining CVP, pulmonary artery wedge pressure (PAWP) and VExUS. When CVP exceeds 8-12 mmHg or equals PAWP and VExUS shows mild or moderate congestion, decreasing RV preload (e.g. through diuresis) might improve hemodynamics (LV filling and interventricular interaction) (Giannakoulas et al., 2025). Another possibility is to use VExUS in parallel with elements of POCUS, especially portal vein pulsatility and cardiac function. High portal pulsatility and altered patterns of cardiac function suggest both volume and cardiac-driven congestion demanding fluid removal and systolic cardiac function improvement. With altered cardiac function and normal portal vein pulsatility, the congestion is probably primarily cardiac-driven. However, this does not mean that fluid removal is contraindicated in this case, but rather that it will most likely be insufficient. The situation is even more complicated when one considers that patients with congestion can be fluid responsive (Pierre-Grégoire, 2025). All of this leads us to conclude that VExUS is a useful and promising method, but one that as a sole tool, cannot reliably assess the appropriateness of fluid administration or removal.

3.3. Fluid selection

ESC Statement on RVF management and ESC Guidelines on PE comment only briefly on the choice of fluid for administration. They both mention saline or Ringer’s lactate in one of the summary tables (Harjola et al., 2016; Konstantinides et al., 2020). The AHA statement on RVF and ESC statement on RVF secondary to increased afterload, on the other hand are silent on the subject (Arrigo et al., 2024; Konstam et al., 2018). Although in ARVF, fluid volume may be more important than the choice of a specific fluid, we can examine more general studies on fluid therapy in intensive care and attempt to make a cautious extrapolation.

Several large RCTs comparing saline and balanced crystalloid usage were published in recent years. Examples of such trials are Isotonic Solutions and Major Adverse Renal Events Trial (SMART), published in 2018. This large study included 15,802 patients hospitalized in five intensive care units at an academic center. They received saline (0.9% sodium chloride) or balanced crystalloids (lactated Ringer's solution or Plasma-Lyte A). Among the balanced-crystalloids group (n = 7,942) 14.3% had a major kidney event (death from any cause, new renal replacement therapy or persistent renal dysfunction) within 30 days of therapy. In the saline group (n = 7,860) this percentage was 15.4% (marginal odds ratio 0.91, 95% CI 0.84-0.99, conditional odds ratio 0.90, 95% CI 0.82-0.99, p = 0.04). However, differences in the individual components of the major kidney events were not statistically significant between the two groups (Semler et al., 2018). In the same year another, similar trial was published, this time concerning noncritically ill adults. The trial included 13,347 patients who were treated in the emergency department and were subsequently hospitalized outside the ICU. The length of hospitalization did not differ between saline and balanced crystalloid group. However, the latter group had a lower frequency of major adverse kidney events within 30 days than the saline group (4.5% vs 5.6%; adjusted odds ratio 0.82, 95% CI 0.70-0.95, p = 0.01) (Self et al., 2018). However, a more recent, large multicenter RCT in ICU patients (unlike the single-center SMART study) found no evidence that balanced crystalloids are more beneficial than saline (Finfer et al., 2022).

The recently published Surviving Sepsis Campaign guidelines suggest using balanced crystalloids over 0.9% saline for adults with sepsis or septic shock (Prescott et al., 2026). This recommendation was based on meta-analysis of 11 trials (n = 35,884) and individual participant data meta-analysis of five RCTs (n = 6,753). Mortality in the balanced crystalloids group was possibly lower than in patients treated with saline (Odds ratio [OR] 0.94, 95% CI 0.85-1.04) as was the need for renal replacement therapy (OR 0.86, 95% CI 0.74-0.99). This evidence, however, does not apply directly to ARVF. Nonetheless, its general nature allows us to draw the indirect conclusion that balanced crystalloids may also be beneficial in RVF. The extent of this benefit, however, remains unclear.

4. Discussion

The evidence on fluid therapy guidance in ARVF appears limited. The main scientific statements regarding this syndrome devote relatively little space to the topic. Their recommendations focus on indications for fluid administration (fluid responsiveness prediction), with emphasis on clinical signs and CVP. The main contraindications are obvious peripheral edema, a palpable jugular venous pulse and CVP exceeding 8-12 mmHg. It is also emphasized that fluid administration requires caution as patients with ARVF might be fluid responsive but excess RV preload can lead to deterioration once the volume limit is reached. The role of invasive hemodynamic monitoring is regarded as very helpful in determining the optimal CVP. Monitoring of volume loading is also widely recommended, whether by CVP or more sophisticated hemodynamic monitoring. However these documents do not mention other methods of assessing volume status, such as POCUS, and, even for the frequently cited CVP, do not go beyond the already broad 8–12 mmHg cut-of mentioned above (Arrigo et al., 2024; Harjola et al., 2016; Konstam et al., 2018; Konstantinides et al., 2020).

Other studies address the matter more broadly but the level of evidence is correspondingly lower. Monitoring of volume loading by CVP is cited as useful, since a rapid change in its value (e.g. 5 mmHg from baseline) is a signal that further administration might cause adverse effects (Giannakoulas et al., 2025). POCUS and its specialized congestion-assessment component, VExUS - might be an interesting extension of such a method, especially useful when CVP measurement is not available. An example of such an approach might be combining CVP with VExUS: CVP exceeding 8-12 mmHg or equal to PAWP together with mild to moderate congestion on VExUS suggests the patient is unlikely to benefit from further volume loading (Giannakoulas et al., 2025).

The matter of using POCUS (including VExUS) in fluid responsiveness prediction is also addressed in the literature. There are studies describing IVC-CI, IVC diameter or similar parameters of other veins as tools for guiding volume loading (Jassim et al., 2019; Kumar et al., 2023, 2024). However, large meta-analyses suggest that this approach has serious limitations reflected in sensitivity, specificity and AUC (Kim et al., 2021; Orso et al., 2020). VExUS is a relatively new and useful method of assessing congestion and its severity. It is especially beneficial in cases of congestion with normal CVP (“waterfall phenomenon”) (Si et al., 2026). However, since it reflects the interaction between volume load and heart function, it should not be used alone to assess fluid status or related therapeutic strategy (Pierre-Grégoire, 2025; Si et al., 2026). Imaging methods should serve as one of several tools, rather than as a standalone basis for decisions. This is all the more important since, as noted, most studies on that matter do not concern ARVF directly. Taking into account that scientific statements on ARVF refer to hemodynamic monitoring (CVP and more sophisticated methods as CO measurement) as useful tools and the fact that reliable prediction of fluid responsiveness is in most cases not possible, a fluid challenge under hemodynamic monitoring seems worth considering .

In terms of fluid selection, scientific statements mention saline or Ringer's lactate as equivalent (Harjola et al., 2016; Konstantinides et al., 2020). Analysis of recent RCTs comparing saline with balanced crystalloids and the newest Surviving Sepsis Campaign guidelines (which reviewed a number of such trials) leads to the cautious conclusion that balanced crystalloids could be more beneficial for patients (Finfer et al., 2022; Prescott et al., 2026; Self et al., 2018; Semler et al., 2018). However, this remains uncertain, especially in ARVF where these findings must be extrapolated indirectly.

5. Conclusions

Fluid therapy in ARVF is not a thoroughly explored topic, as reflected in the general recommendations of the scientific statements devoted to this syndrome. POCUS and especially VExUS are attractive methods of assessing congestion but have real limitations and should therefore not be used as the sole method. Moreover, most studies on the subject do not concern ARVF directly. Combining it with CVP is a reasonable approach, but even then, because of the wide CVP cut-off (8–12 mmHg), the decision on volume loading may be difficult . In such unclear cases, a cautious fluid challenge with small-volume boluses under hemodynamic monitoring seems to be a suitable solution.

Disclosure

Author Contributions

Conceptualization: AU, MK, TK, MM, DG
Methodology: AU, KI, TK, MM, DG
Investigation: AU, MKu, WG-K
Resources: AU, MM, MK, DG, TK, GP
Data curation: AU, AG, KI, GP
Drafting: AU, KI, HB, AG, GP, PK
Writing review and editing: AU, WG-K, MKu, PK, HB
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Declaration of the use of generative AI

During the preparation of this work, the authors used AI tools for the purpose of language editing and stylistic refinement to improve clarity and readability of the manuscript. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the accuracy, integrity and conclusions of the publication

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