

gests elevated systolic PAP; in the absence of precapillary pulmonary hypertension (e.g., pulmonary embolism, COPD, or ARDS), this finding – in conjunction with other echocardiographic parameters (reduced e' velocity, elevated E/e' ratio, and increased LAVi) – supports the presence of elevated left-sided filling pressures. In patients with precapillary aetiology, elevated PAP does not imply increased LV filling pressure and should be interpreted with caution [17].

Tissue Doppler Imaging (TDI) of the Mitral Annulus

- e' septal > 6 cm/s, e' lateral > 7 cm/s (approximately).
- E/e' is used to estimate LV filling pressures.
- $E/e' < 8$ suggests normal LAP, whereas $E/e' > 14$ in sinus rhythm indicates elevated LAP; $E/A > 2$ typically indicates restrictive filling with high filling pressures [17].

Left Atrial Emptying Fraction (LAEF)

- LAEF [%] = $(LAV_{max} - LAV_{min}) / LAV_{max} \times 100$; reference range ≈ 48 –71% [23]. Interpretation is most reliable in sinus rhythm (ideally 1–4 hours post-cardioversion).

Classification of LV diastolic dysfunction

Assessment of diastolic function is an integral part of TTE in critically ill patients with NOAF. Based on the combination of parameters (E , E/A , E/e' , LAVi, TR Vmax), diastolic dysfunction can be classified into three grades (see Tab. 1) [17]. Loss of atrial contribution in NOAF most significantly reduces stroke volume in patients with impaired relaxation and pseudonormalisation, wherein LV filling is significantly dependent on active left atrial function [24]. In patients with sepsis and septic shock, diastolic dysfunction and left atrial remodelling are considered as part of the arrhythmogenic substrate for NOAF, but a clear semi-quantitative or quantitative risk score based on these parameters has not yet been validated.

Echocardiographic predictors of NOAF – overview of clinical studies

In the prospective study by Makrygiannis et al. involving 133 critically ill patients, an association was demonstrated between the incidence of NOAF and echocardiographic findings on TTE: severe systolic dysfunction with left ventricular ejection fraction (LVEF) < 35%, left atrial dilatation, and diastolic dysfunction [25].

In the study by Lancini et al., conducted in intensive care patients (31% with sepsis), the authors analysed the relationship between "NOAF burden", defined as the ratio of NOAF duration to total ECG monitoring time, and clinical, laboratory, and echocardiographic parameters. Of all echocardiographic indicators, left atrial area (LAA) was an independent predictor of a higher NOAF burden; patients with a high burden had larger LAA ($24.4 \pm 6.8 \text{ cm}^2$) than those with a low burden ($21.3 \pm 5.5 \text{ cm}^2$; $p = 0.001$). The median NOAF burden was 7% of the time spent in intensive care (IQR 2.1–24.8%) [26].

In the prospective randomised controlled PRASE study (Propafenone versus Amiodarone in Supraventricular Arrhythmias in Septic Shock) of new-onset atrial fibrillation in patients with LVEF $\geq 35\%$, in the subgroup of patients with dilated left atrium (LAVi $\geq 40 \text{ ml/m}^2$), amiodarone treatment was more effective, whilst in those with non-dilated left atrium (LAVi < 40 ml/m^2), propafenone was more effective ($p = 0.01$) [27]. Post-hoc analysis further showed that, in patients with LAVi < 40 ml/m^2 , propafenone led to faster cardioversion than amiodarone (3.6 hours vs. 8.5 hours, $p = 0.009$) and to fewer recurrences (50% vs. 76.8%, $p = 0.001$) [28]. Conversely, in patients with LAVi $\geq 40 \text{ ml/m}^2$, amiodarone administration was more effective, with a shorter time to cardioversion (median: 66.5 hours, IQR 14.0–121.0 hours) compared to propafenone (median: 171 hours, IQR 62.8–235.0 hours, $p = 0.023$). In patients with non-dilated left atrium, propafenone treatment was associated with better survival (HR 0.6; 95% CI 0.4–0.9; $p = 0.014$), and this effect persisted for up to one year (HR 0.55; 95% CI 0.35–0.86; $p = 0.008$).

Left atrial two-dimensional parameters, specifically LAVi < 40 ml/m^2 and LA ESD $\leq 45 \text{ mm}$, were shown in an exploratory sub-study of the PRASE trial as possible parameters for a decision between the rhythm and rate control strategies in patients with NOAF. By contrast, LA ESD > 46 mm was a weak predictor of multiple NOAF recurrences after cardioversion. Given their preload dependence, LAVi and LA ESD represent static parameters that have a lower predictive ability for SR maintenance compared to functional indicators (AVTI and LAEF). AVTI > 6.8 cm (AUC 0.65 and $p = 0.001$) and LAEF > 38.4% (AUC 0.69 and $p < 0.001$) at 4 hours post-cardioversion significantly predicted SR maintenance and can assist in the decision on therapeutic strategy [20]. Therefore, in critically ill patients with NOAF, functional echocardiographic parameters (AVTI and LAEF) should be considered in final decision-making over static morphological dimensions (LA ESD, LAA, and LAVi). The parameters indicating a potentially more aggressive approach to achieve rhythm control in NOAF treatment are summarised in Tab. 2.

Tab. 1. Diastolic dysfunction (assessed in sinus rhythm without significant valvular disease, in an euvoaemic patient without vasoparalysis)

Diastolic dysfunction	Echocardiographic parameters	LA anatomy	LAP (approximate mean pressure values)
Grade 1 / Impaired relaxation	e' reduced (septal $\leq 6 \text{ cm/s}$ or lateral $\leq 7 \text{ cm/s}$); $E/A < 0.8$; $E/e' < 14$; TR Vmax < 2.8 m/s	LAVi < 34 ml/m^2	LAP at rest normal $\leq 15 \text{ mmHg}$
Grade 2 / Pseudonormalisation	e' reduced; $E/A 0.8$ – 2.0 ; $E/e' \geq 14$ and/or TR Vmax $\geq 2.8 \text{ m/s}$ (PASP $\geq 35 \text{ mmHg}$)	LA enlarged (LAVi $\geq 34 \text{ ml/m}^2$)	Mildly to moderately elevated LAP 16–25 mmHg
Grade 3 / Restrictive pattern	e' reduced; $E/A > 2$; DT < 150 ms; $E/e' \geq 14$ and/or TR Vmax $\geq 2.8 \text{ m/s}$	LA markedly enlarged	Significantly elevated filling pressures; restrictive profile; LAP often exceeding 25 mmHg

Legend: LA – left atrium; LAP – left atrial pressure; E – early diastolic filling wave from pulsed-wave Doppler; A – late diastolic atrial contraction wave from pulsed-wave Doppler; E/A – ratio of E and A waves; e' – wave measured from tissue Doppler at the mitral annulus; E/e' – ratio of E and e' waves; LAVi – left atrial volume index; TR Vmax – maximum velocity of tricuspid regurgitation; DT – deceleration time; PASP – pulmonary artery systolic pressure.