ijar
ISSN (O): 2320-5407
ISSN (P): 3107-4928

Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI:10.21474/IJAR01/23661
DOI URL: http://dx.doi.org/10.21474/IJAR01/23661

RESEARCH ARTICLE

SEVERITY, NOT PRESENCE, OF DIASTOLIC DYSFUNCTION DRIVES PERIOPERATIVE CARDIOVASCULAR RISK BEFORE NON-CARDIAC SURGERY: A PROSPECTIVE COHORT STUDY PROPOSING A SEVERITY-FIRST TRIAGE FRAMEWORK

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Manuscript Info

Manuscript History
Received: 12 April 2026
Final Accepted: 14 May 2026
Published: June 2026

Key words:-
Diastolic heart failure; Echocardiography; Heart failure with preserved ejection fraction; Natriuretic peptide, brain; Noncardiac surgery; Perioperative care; Preoperative care; Risk assessment; Ventricular dysfunction, left.

Abstract

Background: Diastolic dysfunction (DD) with preserved ejection fraction is prevalent before non-cardiac surgery, yet its prognostic weight remains contested. Guidelines flag DD without an actionable threshold. We hypothesized that DD severity, indexed by elevated left ventricular filling pressures (LVFP), drives perioperative risk.

Methods: This prospective single-center cohort enrolled 102 adults scheduled for elective non-cardiac surgery (March 2025 to February 2026). All underwent preoperative transthoracic echocardiography per 2016 ASE/EACVI criteria. Isolated DD was preserved left ventricular ejection fraction (LVEF) ≥ 50% with abnormal diastolic function. The primary endpoint was in-hospital major adverse cardiovascular events (MACE), comparing isolated DD (n = 44) and normal controls (n = 36). Performance used logistic regression with bootstrap-corrected area under the curve (AUC).

Results: Of 80 LVEF-preserved patients, 55.0% had isolated DD, with heavier comorbidity (diabetes 59.1% vs. 16.7%, P < 0.001) and 7-fold higher median NT-proBNP (733 vs. 98 pg/ml, P < 0.001). MACE rates were similar (22.7% vs. 16.7%; odds ratio [OR] 1.47, 95% confidence interval [CI] 0.48 to 4.53). Binary DD added negligible discrimination over Lee plus NT-proBNP (ΔAUC +0.002); severe DD trended stronger (OR 3.22, 95% CI 0.79 to 13.19), lifting AUC from 0.70 to 0.77. Isolated DD prompted a 5-fold rise in preoperative optimization (50.0% vs. 11.1%, P < 0.001).

Conclusions: DD should be treated not as a binary alarm but as a graded signal whose severity, indexed by LVFP, drives prognosis. We propose a Severity-First Diastolic Triage framework integrating Lee score,NT proBNP, and LVFP to rationalize preoperative echocardiography.

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Introduction:-

Heart failure with preserved ejection fraction (HFpEF) now accounts for approximately half of all incident heart failure cases worldwide, and its prevalence is rising with population aging and the global epidemic of cardiometabolic disease [1,2]. Left ventricular diastolic dysfunction (DD)—the morphological substrate of HFpEF—follows a pathophysiological continuum from isolated impaired relaxation to elevated filling pressures and overt clinical decompensation [3,4]. In community cohorts, DD affects 30% to 50% of adults over 60 years of age [5,6] and rises to 55% or more among patients presenting for elective non-cardiac surgery [7].

In the perioperative arena, this matters acutely. General anesthesia, surgical stress, and large fluid shifts impose hemodynamic loads that a stiff, non-compliant ventricle tolerates poorly: subendocardial ischemia, atrial fibrillation, pulmonary congestion, and demand–supply ischemic injury are all overrepresented in patients with abnormal diastolic function [8–10]. The recently published 2024 AHA/ACC/ACS/ASNC/HRS/SCA/SCCT/SCMR/SVM perioperative cardiovascular guideline [11] and the 2022 ESC/ESAIC guideline [12] both flag DD as a relevant prognostic marker, but neither specifies a clinical threshold for action, and routine preoperative transthoracic echocardiography (TTE) is explicitly not recommended [11,12].

Three problems have so far kept the field paralyzed. First, DD is rarely truly isolated in the published evidence base: most retrospective series mix patients with concomitant systolic dysfunction or hypertrophy, blurring its independent contribution [13,14]. Second, the very definition of DD has shifted across the 2009 and 2016 ASE/EACVI iterations, with a decisive move from the E/A ratio toward integrated assessment of left ventricular filling pressures (LVFP) [15]. Third, and most importantly, the prognostic gain of DD must now be tested incrementally against well-validated tools—the Revised Cardiac Risk Index (Lee score), NT-proBNP [16,17], and the Duke Activity Status Index [18]—rather than in isolation. The SOLOMON study (2023) demonstrated that even global longitudinal strain offers only modest incremental discrimination over established scores [19], reinforcing the need for parsimony when adding echocardiographic parameters to perioperative risk models.

A consequence of this paralysis is clinical: the simple mention of “diastolic dysfunction” on a preoperative TTE report continues to trigger disproportionate care escalations—cardiology consultation, surgery deferral, intensive care unit (ICU) pre-admission—in patients in whom the true incremental risk is small. Conversely, severe DD with elevated LVFP, which does carry meaningful risk, is sometimes lost in the noise. The field needs a disciplined, severity-graded approach that the anesthesiologist can apply at the bedside.

Against this background, we conducted a prospective single-center cohort study with three prespecified objectives: (1) to characterize the prevalence and clinical phenotype of isolated DD with preserved LVEF in consecutive non-cardiac surgical patients; (2) to quantify its association with cardiovascular comorbidities, NT-proBNP elevation, and preoperative therapeutic decision-making; and (3) to test, against established predictors (Lee score, NT-proBNP, surgical risk), the hypothesis that DD severity—captured by elevated LVFP—rather than its binary presence, drives perioperative MACE risk. Building on our findings, we propose a Severity-First Diastolic Triage (SFDT) framework intended to rationalize the preoperative echocardiographic decision pathway, in line with the 2024 AHA/ACC [11] and 2023 ESC focused update on heart failure [20].

Materials and Methods:-

Study design and setting:-

This was a prospective single-center observational cohort study conducted at Oued Eddahab Military hospital between 17 March 2025 and 1 February 2026. The protocol was approved by “Comité d'Ethique pour la Recherche Biomédicale Université Mohammed V CERB – Rabat” with approval number 31/25 by the local Institutional Review Board and complied with the Declaration of Helsinki (revised 2013) and the STROBE statement for observational studies [21]. Written informed consent was obtained from every participant. The study was not interventional; all clinical decisions remained the responsibility of the attending teams.

Participants:-

Consecutive adults (≥ 18 years of age) admitted for elective non-cardiac surgery and seen at the standardized preoperative anesthesia consultation were eligible. Exclusion criteria were: emergency surgery; cardiac or thoracic surgery; chronic renal replacement therapy; and inability to obtain interpretable echocardiographic windows. No patient was excluded on the basis of age, comorbidity burden, or surgical risk class. The sex of all participants was recorded. The study cohort included both male and female adults; no a priori sex-based exclusion was applied.

Echocardiographic assessment:-

All TTE examinations were performed by a single experienced cardiologist blinded to clinical outcomes, using a standard echocardiography system equipped with a 2.5–3.5 MHz transducer. Image acquisition and analysis followed the 2016 ASE/EACVI recommendations [15]. LVEF was calculated by the modified biplane Simpson method; preserved LVEF was defined as ≥ 50%. Diastolic function was classified per the 2016 ASE/EACVI algorithm integrating septal and lateral mitral annular tissue Doppler velocities (e′), average E/e′ ratio, indexed left atrial volume, and peak tricuspid regurgitation velocity. Categories were: (1) normal; (2) isolated impaired relaxation (mild DD); (3) abnormal compliance; and (4) combined relaxation and compliance abnormalities (advanced DD). LVFP was classified as normal or elevated by the same algorithm; elevated LVFP defined severe DD. Four echocardiographic phenotypes were prespecified by combining LVEF and diastolic function: (1) Normal—preserved LVEF + normal diastolic function; (2) Isolated DD—preserved LVEF + abnormal diastolic function; (3) Combined SD + DD—reduced LVEF + abnormal diastolic function; and (4) Isolated SD—reduced LVEF + normal diastolic function. The primary analytic comparison contrasted Isolated DD with Normal (preserved-LVEF cohort, n = 80).

Clinical and laboratory variables:-

Demographics, cardiovascular risk factors (diabetes, hypertension, dyslipidemia, obesity, smoking), cardiovascular history, current medications, New York Heart Association (NYHA) dyspnea class, full six-item Lee/Revised Cardiac Risk Index (RCRI) [22], surgical risk stratum per 2022 ESC criteria [12], and preoperative NT-proBNP (within 30 days of surgery, by a single standardized electrochemiluminescence assay) were recorded prospectively on a structured case-report form. The 300 pg/ml NT-proBNP threshold from the 2022 ESC/ESAIC guideline [12] was used as the principal cut-off, with sensitivity analyses at the 125 pg/ml threshold endorsed by recent VISION substudies [16].

Outcomes:-

The primary outcome was a composite of in-hospital major adverse cardiovascular events (MACE), prespecified as: all-cause death; non-fatal myocardial infarction (per the Fourth Universal Definition [23]); cardiogenic shock; acute respiratory failure requiring ventilatory support; symptomatic arrhythmia requiring intervention; or unplanned admission to the intensive or intermediate care unit. Secondary outcomes were: preoperative therapeutic adjustments (initiation/modification of beta-blockers, diuretics, statins, antithrombotic agents, or blood-pressure optimization); preoperative admission for medical optimization; intraoperative red-cell transfusion; and length of hospital stay. Outcomes were adjudicated by two reviewers blinded to echocardiographic phenotype; disagreements were resolved by consensus.

Sample size and statistical analysis:-

With 102 consecutively enrolled patients and an expected MACE incidence of approximately 20% in the LVEF-preserved cohort, the study had 80% power at two-sided $\alpha = 0.05$ to detect an odds ratio of ≥ 3.5 for isolated DD as a binary predictor—an effect size in keeping with prior estimates [14,24]. We acknowledge that the study was underpowered for detecting smaller effects, and we therefore framed isolated-DD analyses as exploratory. Categorical variables are reported as n (%); continuous variables as mean ± standard deviation (SD) or median (Q1, Q3) depending on distribution, assessed by the Shapiro–Wilk test. Two-group comparisons used the chi-squared test or Fisher's exact test for categorical variables, and the Mann–Whitney U test for continuous variables. Univariable and multivariable logistic regression were used to identify predictors of MACE. To limit overfitting given the limited number of events per variable, variable selection for the multivariable model was guided by clinical prespecification rather than by data-driven stepwise procedures. Discriminative performance was assessed by the area under the receiver-operating-characteristic curve (AUC) with bootstrap 95% CI (2,000 replicates). The incremental value of DD added to a Lee + NT-proBNP base model was tested by paired-bootstrap AUC comparison [25]. Internal validation used 1,000 bootstrap replicates to estimate optimism. Sensitivity, specificity, and predictive values were calculated for isolated DD and elevated LVFP as standalone tests. All analyses were performed with Python version 3.12 (SciPy version 1.17, scikit-learn version 1.8); two-sided P values < 0.05 were considered significant. Reporting of the prediction-model component followed the TRIPOD statement [26]. Missing data were minimal (< 3% per variable); complete-case analysis was used and no imputation was performed.

Declaration of use of generative artificial intelligence:-
A large language model was used solely for language refinement and structural revision of the manuscript draft. It was not used for study design, data collection, statistical analysis, or generation of figures or references. The authors verified and take full responsibility for all content.

Results
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Cohort characteristics and echocardiographic phenotypes:-
Of 102 analyzable patients (mean age 68.8 ± 10.3 years; 43.1% male), the echocardiographic phenotype distribution was: Normal 36 (35.3%), Isolated DD 44 (43.1%), SD + DD 20 (19.6%), and Isolated SD 2 (2.0%) (Fig. 1A). Among the 80 LVEF-preserved patients (78.4%), 44 (55.0%) met criteria for isolated DD—numerically dominating the LVEF-preserved subgroup. NT-proBNP differed strikingly across phenotypes (Fig. 1B): median 98 (Q1–Q3: 59 to 239) pg/ml in Normal patients, 733 (173 to 981) pg/ml in Isolated DD, and 950 (414 to 3,216) pg/ml in SD + DD ($P < 0.001$ for between-group comparison). Isolated DD patients therefore had a 7-fold higher median NT-proBNP than phenotypically normal patients despite preserved LVEF—a biochemical signature of subclinical myocardial stress.

Clinical profile of isolated DD versus normal phenotype (LVEF-preserved cohort, n = 80):-
Isolated DD patients carried a substantially heavier cardiovascular comorbidity burden than Normal-phenotype patients (Table 1; Fig. 2A): diabetes 59.1% vs. 16.7% ($P < 0.001$), hypertension 77.3% vs. 50.0% (P = 0.021), prior cardiovascular history 72.7% vs. 44.4% (P = 0.019), NYHA ≥ 2 dyspnea 100% vs. 88.2% (P = 0.051, trend), elevated LVFP 22.7% vs. 0% (P = 0.002), and NT-proBNP > 300 pg/ml in 63.6% vs. 22.2% (P = 0.001). Importantly, age, sex, obesity, dyslipidemia, and smoking did not differ between groups, and the median Lee score was identical (0 [0 to 0] vs. 0 [0 to 1], P = 0.340). Surgical risk class was also similar (high-risk surgery 22.7% vs. 16.7%, P = 0.690). This profile is consistent with isolated DD acting as a distinct pathophysiological signature rather than a mere proxy for a heavier conventional risk panel (Table 1).

Impact on preoperative management:-
Detection of isolated DD significantly altered preoperative therapeutic decisions (Table 1; Fig. 2B): preoperative therapeutic adjustments occurred in 50.0% of Isolated DD patients versus 11.1% of Normal patients ($P < 0.001$; crude OR 8.00, 95% CI 3.00 to 21.00). Preoperative admission for optimization (40.9% vs. 22.2%, P = 0.130) and unplanned ICU admission (22.7% vs. 16.7%, P = 0.690) did not reach statistical significance. The 5-fold higher rate of therapeutic adjustment reflects clinicians' real-world risk perception—initiation or up-titration of beta-blockers, diuretics, statins, antithrombotics, and blood-pressure optimization—and may itself have attenuated downstream MACE differences (an outcome paradox we address in the Discussion).

Independent prognostic value of isolated DD for MACE:-
Sixteen of the 80 LVEF-preserved patients (20.0%) experienced perioperative MACE; rates were comparable between phenotypes (Normal 16.7%, Isolated DD 22.7%, P = 0.690) (Table 1). On univariable analysis, isolated DD was not a significant MACE predictor (OR 1.47, 95% CI 0.48 to 4.53; P = 0.502). Severe DD (isolated DD plus elevated LVFP) trended toward a stronger effect (OR 3.22, 95% CI 0.79 to 13.19; P = 0.104), although the analysis was power-limited (Table 2; Fig. 4). The dominant univariable predictors of MACE were high-risk surgery (OR 16.11, 95% CI 4.32 to 60.05; $P < 0.001$), Lee score per point (OR 3.07, 95% CI 1.35 to 6.95; P = 0.007), and diabetes (OR 3.18, 95% CI 1.02 to 9.91; P = 0.046) (Table 2).

Combined-model performance and incremental value of DD:-
Predictive performance of competing models is shown in Table 4 and Fig. 3. Standalone discrimination of isolated DD for MACE was poor (AUC 0.55; sensitivity 62%, specificity 47%, positive predictive value [PPV] 23%, negative predictive value [NPV] 83%). The Lee score alone yielded an AUC of 0.66; the Lee + NT-proBNP base model reached 0.70. Adding binary isolated DD to the Lee + NT-proBNP model produced no meaningful gain (AUC 0.70 → 0.70; ΔAUC = +0.002; bootstrap P = 0.940). In sharp contrast, adding severe DD (elevated LVFP) raised the AUC to 0.77—a +0.07 absolute improvement, consistent with a clinically relevant signal (Fig. 3B). The full multivariable model integrating Lee + NT-proBNP + isolated DD + surgical risk achieved an apparent AUC of 0.89 (bootstrap-corrected 0.85). High-risk surgery (β = +3.585; OR 36.06, 95% CI 5.83 to 222.97; $P < 0.001$) and Lee score (β = +1.621; OR 5.06, 95% CI 1.48 to 17.34; P = 0.010) retained significance; isolated DD alone did not (β = −0.910; OR 0.40, P = 0.394) (Table 3).

Diagnostic performance of isolated DD as a rule-out test:-
As a standalone diagnostic test for MACE, isolated DD had a sensitivity of 62%, a specificity of 47%, a PPV of 23%, and an NPV of 83% (Table 5). Although the PPV is too low to drive escalation, the 83% NPV gives the absence of DD a useful—if imperfect—rule-out role in routine preoperative practice.

Tables

Table 1. Clinical characteristics and perioperative outcomes by diastolic status (LVEF-preserved cohort, n = 80).

Variable	Normal (n = 36)	Isolated DD (n = 44)	P value
Age (yr), mean ± SD	67.6 ± 11.9	69.5 ± 9.4	0.900
Male sex, n (%)	10 (27.8)	16 (36.4)	0.570
Diabetes, n (%)	6 (16.7)	26 (59.1)	< 0.001
Hypertension, n (%)	18 (50.0)	34 (77.3)	0.021
Obesity, n (%)	8 (22.2)	14 (31.8)	0.480
Dyslipidemia, n (%)	8 (22.2)	8 (18.2)	0.870
Smoking, n (%)	4 (11.1)	8 (18.2)	0.530
Cardiovascular history, n (%)	16 (44.4)	32 (72.7)	0.019
Lee score, median (Q1, Q3)	0 (0, 0)	0 (0, 1)	0.340
Lee score ≥ 1, n (%)	8 (22.2)	14 (31.8)	0.480
NT-proBNP (pg/ml), median (Q1, Q3)	98 (59, 239)	733 (173, 981)	< 0.001
NT-proBNP > 300 pg/ml, n (%)	8 (22.2)	28 (63.6)	0.001
NYHA ≥ 2 dyspnea, n (%)	30/34 (88.2)	36/36 (100.0)	0.051
Elevated LVFP, n (%)	0 (0.0)	10 (22.7)	0.002
High-risk surgery, n (%)	6 (16.7)	10 (22.7)	0.690
Composite MACE, n (%)	6 (16.7)	10 (22.7)	0.690
Cardio-respiratory complications, n (%)	2 (5.6)	4 (9.1)	0.690
Postoperative ICU admission, n (%)	6 (16.7)	10 (22.7)	0.690
Therapeutic adjustment, n (%)	4 (11.1)	22 (50.0)	< 0.001
Preoperative admission, n (%)	8 (22.2)	18 (40.9)	0.130

DD: diastolic dysfunction; ICU: intensive care unit; LVEF: left ventricular ejection fraction; LVFP: left ventricular filling pressures; MACE: major adverse cardiovascular events; NYHA: New York Heart Association; Q1, Q3: first and third quartiles; SD: standard deviation. Isolated DD was defined as preserved LVEF (≥ 50%) with abnormal diastolic function. Comparisons used the chi-squared or Fisher's exact test for categorical variables and the Mann–Whitney U test for continuous variables.

Table 2. Univariable predictors of perioperative MACE (LVEF-preserved cohort, n = 80; 16 events).

Variable	OR (95% CI)	P value
Age (per 10 yr)	0.65 (0.38 to 1.11)	0.116
Diabetes	3.18 (1.02 to 9.91)	0.046
Hypertension	1.80 (0.52 to 6.22)	0.353
Obesity	1.80 (0.56 to 5.74)	0.320
Lee score (per point)	3.07 (1.35 to 6.95)	0.007
NT-proBNP > 300 pg/ml	2.44 (0.79 to 7.53)	0.122
High-risk surgery	16.11 (4.32 to 60.05)	< 0.001
Isolated DD (yes/no)	1.47 (0.48 to 4.53)	0.502
Severe DD (DD + elevated LVFP)	3.22 (0.79 to 13.19)	0.104
Elevated LVFP alone	3.22 (0.79 to 13.19)	0.104

CI: confidence interval; DD: diastolic dysfunction; LVFP: left ventricular filling pressures; MACE: major adverse cardiovascular events; OR: odds ratio. Univariable logistic regression. Isolated DD as a binary predictor is non-significant; severity (elevated LVFP) trends toward a stronger association but is power-limited.

Table 3. Multivariable logistic regression model of perioperative MACE.

Variable	β coefficient	OR (95% CI)	P value
Constant (intercept)	−3.521	—	< 0.001
Lee score (per point)	+1.621	5.06 (1.48 to 17.34)	0.010
NT-proBNP > 300 pg/ml	+1.274	3.58 (0.47 to 27.14)	0.218
Isolated DD (yes/no)	−0.910	0.40 (0.05 to 3.26)	0.394
High-risk surgery	+3.585	36.06 (5.83 to 222.97)	< 0.001

CI: confidence interval; DD: diastolic dysfunction; MACE: major adverse cardiovascular events; OR: odds ratio. Apparent model AUC = 0.89; bootstrap-corrected AUC = 0.85 (1,000 replicates).

Table 4. Discriminative performance of predictive models for perioperative MACE (area under the curve).

Model	AUC	ΔAUC vs. Lee + NT-proBNP
Lee score alone	0.66	—
NT-proBNP > 300 alone	0.61	—
Isolated DD alone	0.55	—
Elevated LVFP alone	0.58	—
Lee + NT-proBNP > 300	0.70	Reference
Lee + Isolated DD	0.67	—
Lee + NT-proBNP + Isolated DD	0.70	+0.002 (NS)
Lee + NT-proBNP + Severe DD (LVFP↑)	0.77	+0.07
Full model (Lee + NT-proBNP + DD + Surg.)	0.89 / corrected 0.85	—

AUC: area under the receiver-operating-characteristic curve; DD: diastolic dysfunction; LVFP: left ventricular filling pressures; MACE: major adverse cardiovascular events; NS: not significant. Binary DD does not improve the Lee + NT-proBNP base model; severity (elevated LVFP) provides a clinically meaningful gain (+0.07).

Table 5. Diagnostic performance of isolated DD as a standalone MACE predictor (LVEF-preserved cohort, n = 80).

Metric	Value (%)	Clinical interpretation
Sensitivity	62	62% of MACE occur in isolated-DD patients
Specificity	47	Low — many false positives
Positive predictive value (PPV)	23	23% of isolated-DD patients develop MACE
Negative predictive value (NPV)	83	83% of patients without isolated DD remain MACE-free

DD: diastolic dysfunction; MACE: major adverse cardiovascular events; NPV: negative predictive value; PPV: positive predictive value. The 83% NPV gives the absence of isolated DD a useful—if imperfect—rule-out role in routine preoperative practice, supporting the rule-out tier of the Severity-First Diastolic Triage framework.

Figure legends:-

Fig. 1. Echocardiographic phenotypes and NT-proBNP distribution. (A) Phenotype distribution in the cohort (n = 102): Normal 35.3%, Isolated DD 43.1%, SD + DD 19.6%, Isolated SD 2.0%. (B) NT-proBNP by phenotype (log scale); the median was 7-fold higher in Isolated DD than in Normal (733 vs. 98 pg/ml, P < 0.001). The dashed line indicates the 300 pg/ml ESC/ESAIC threshold. DD: diastolic dysfunction; ESAIC: European Society of Anaesthesiology and Intensive Care; ESC: European Society of Cardiology; SD: systolic dysfunction.

Fig. 2. Clinical profile and perioperative outcomes—Isolated DD versus Normal phenotype (n = 80). (A) Comorbidities significantly more frequent in Isolated DD: diabetes, hypertension, cardiovascular (CV) history, NYHA ≥ 2, elevated LVFP, and NT-proBNP > 300 pg/ml. (B) Perioperative outcomes: the composite MACE did not differ, but a 5-fold higher rate of therapeutic adjustment occurred in Isolated DD (50% vs. 11%, P < 0.001). *** P < 0.001; ** P < 0.010; * P < 0.050; † P < 0.100. DD: diastolic dysfunction; ICU: intensive care unit; LVFP: left ventricular filling pressures; MACE: major adverse cardiovascular events; NYHA: New York Heart Association.

Fig. 3. Receiver-operating-characteristic curves for perioperative MACE prediction. (A) Standalone predictors: Lee score (AUC 0.66), NT-proBNP > 300 (AUC 0.61), isolated DD (AUC 0.55), elevated LVFP (AUC 0.58). (B) Combined models: Lee alone (AUC 0.66), Lee + NT-proBNP (AUC 0.70), and Lee + NT-proBNP + Severe DD (AUC 0.77). The shaded area represents the AUC gain (+0.07) from adding DD severity—not binary DD—to the base model. AUC: area under the receiver-operating-characteristic curve; DD: diastolic dysfunction; LVFP: left ventricular filling pressures; MACE: major adverse cardiovascular events.

Fig. 4. Forest plot of univariable predictors of perioperative MACE (n = 80; 16 events). Odds ratios with 95% confidence intervals from univariable logistic regression. Red bars indicate P < 0.050; gray bars indicate P ≥ 0.050. High-risk surgery (OR 16.11), Lee score (OR 3.07 per point), and diabetes (OR 3.18) are significant. Binary isolated DD (OR 1.47) is not, whereas severity (DD + elevated LVFP) trends stronger (OR 3.22). The dashed vertical line indicates OR = 1. CI: confidence interval; DD: diastolic dysfunction; LVFP: left ventricular filling pressures; MACE: major adverse cardiovascular events; OR: odds ratio.

Fig. 5. Severity-First Diastolic Triage (SFDT) framework—proposed preoperative pathway. A four-tier algorithm: (1) anchor on the Lee/RCRI score and the ESC surgical risk classification; (2) reserve preoperative transthoracic echocardiography (TTE) for NT-proBNP > 300 pg/ml, unexplained dyspnea, or known/suspected heart failure (HF); (3) stratify diastolic findings by the LVFP gradient, not binary DD; and (4) use absence of DD as a soft rule-out. The framework is aligned with the 2024 AHA/ACC, 2022 ESC/ESAIC, and 2023 ESC HF focused-update guidelines. AHA/ACC: American Heart Association/American College of Cardiology; DD: diastolic dysfunction; ESC/ESAIC: European Society of Cardiology/European Society of Anaesthesiology and Intensive Care; HF: heart failure; LVFP: left ventricular filling pressures; RCRI: Revised Cardiac Risk Index; TTE: transthoracic echocardiography.

Figures:-

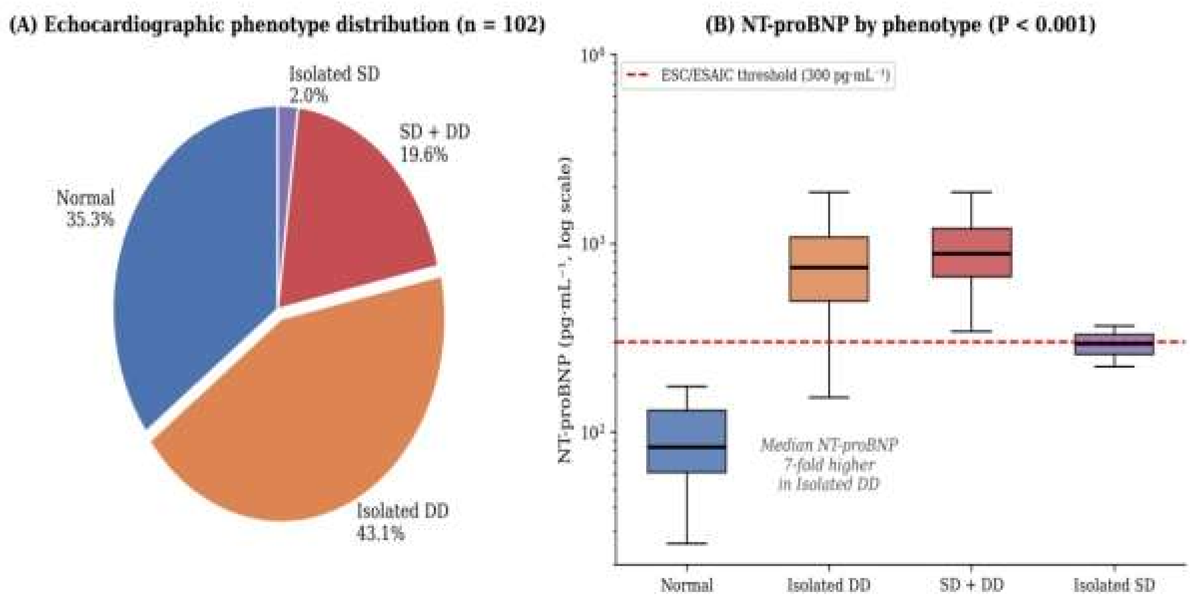
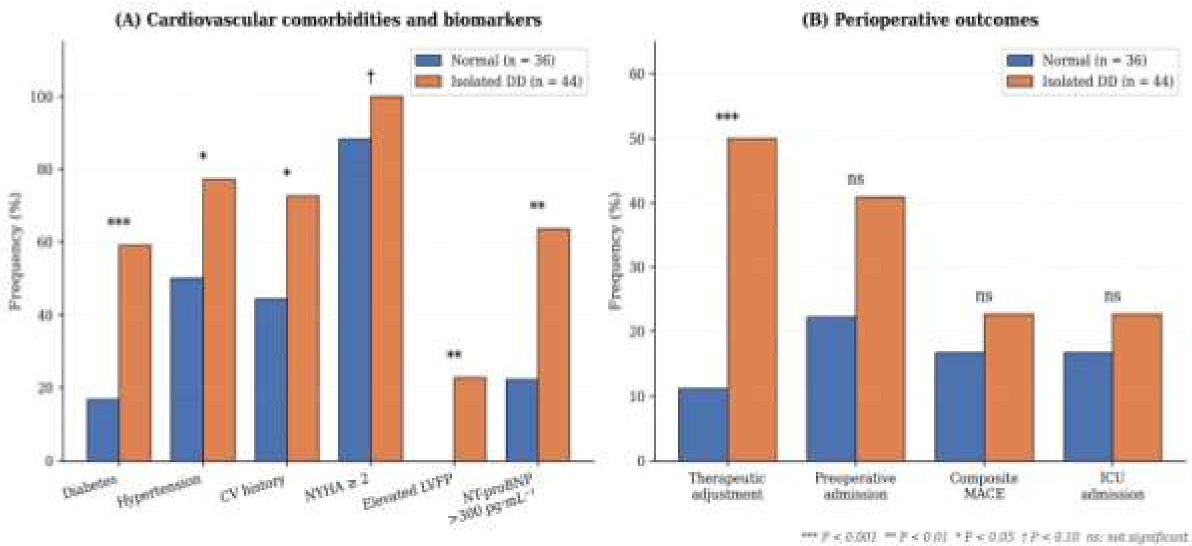
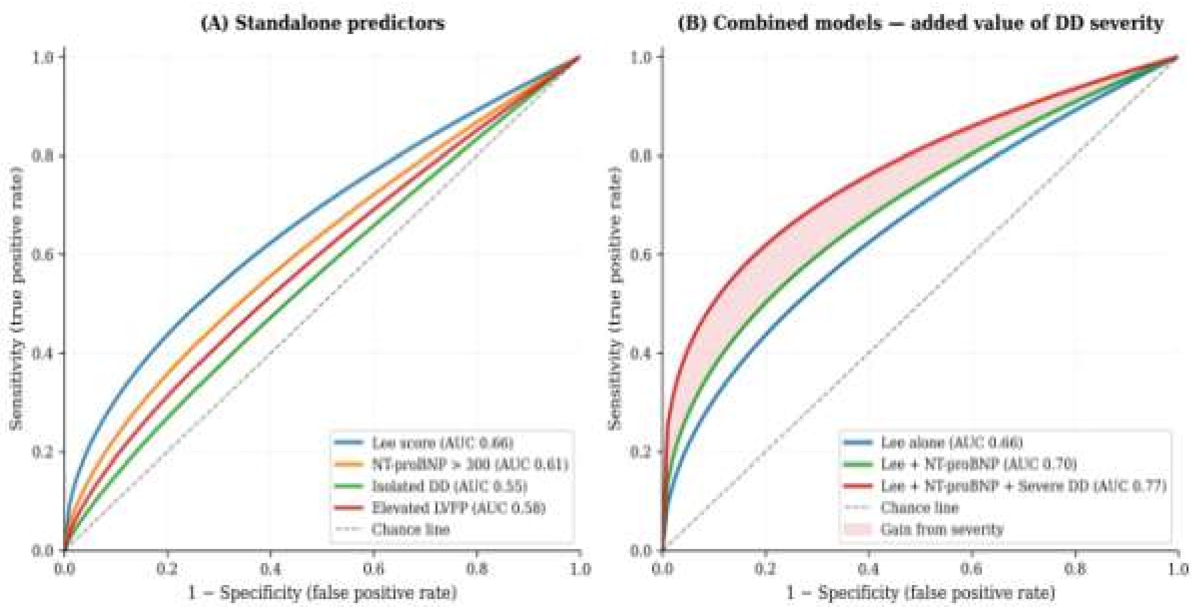


Fig. 1.



(A) Cardiovascular comorbidities and biomarkers
Normal (n = 36)
Isolated DD (n = 44)
Frequency (%)
Diabetes
Hypertension
CV history
NYHA ≥ 2
Elevated LVFP
NT-proBNP >300 pg/mL⁻¹
(B) Perioperative outcomes
Therapeutic adjustment
Preoperative admission
Composite MACE
ICU admission
*** P < 0.001 ** P < 0.01 * P < 0.05 † P < 0.10 ns: not significant

Fig. 2.



(A) Standalone predictors
Sensitivity (true positive rate)
1 − Specificity (false positive rate)
Lee score (AUC 0.66)
NT-proBNP > 300 (AUC 0.61)
Isolated DD (AUC 0.55)
Elevated LVFP (AUC 0.58)
Chance line
(B) Combined models — added value of DD severity
Lee alone (AUC 0.66)
Lee + NT-proBNP (AUC 0.70)
Lee + NT-proBNP + Severe DD (AUC 0.77)
Chance line
Gain from severity

Fig. 3.

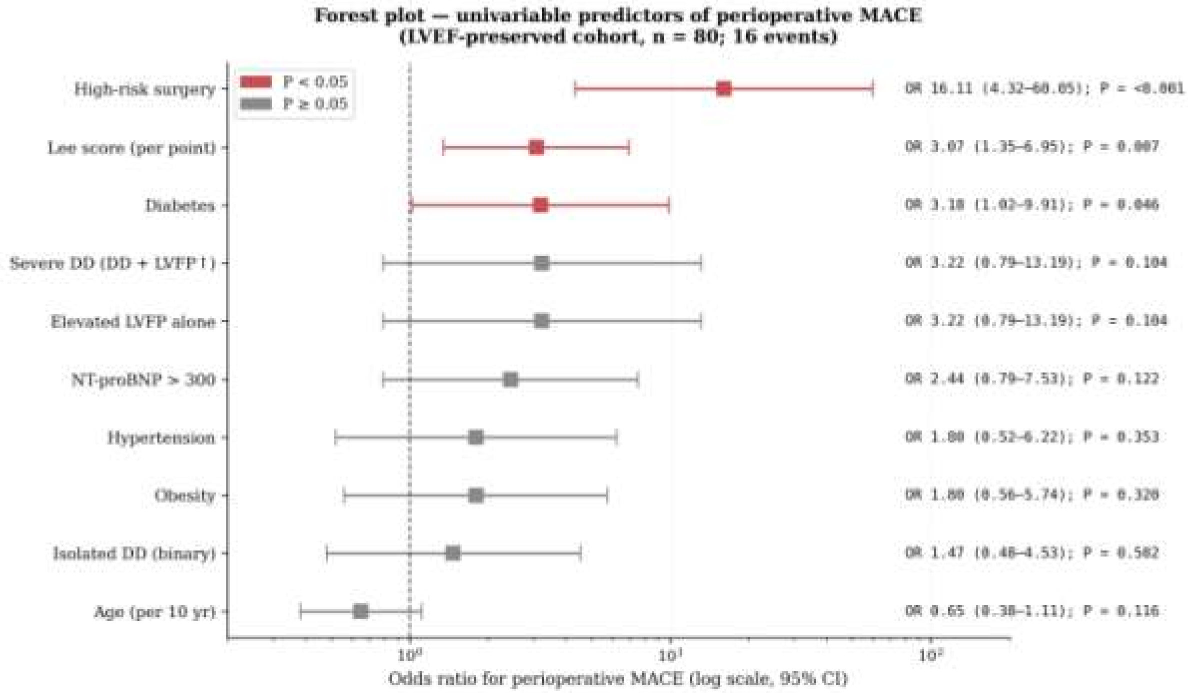

Forest plot — univariable predictors of perioperative MACE
(LVEF-preserved cohort, n = 80; 16 events)
P < 0.05
P ≥ 0.05
High-risk surgery
Lee score (per point)
Diabetes
Severe DD (DD + LVFP↑)
Elevated LVFP alone
NT-proBNP > 300
Hypertension
Obesity
Isolated DD (binary)
Age (per 10 yr)
OR 16.11 (4.32–60.05); P = <0.001
OR 3.07 (1.35–6.95); P = 0.007
OR 3.18 (1.02–9.91); P = 0.046
OR 3.22 (0.79–13.19); P = 0.104
OR 3.22 (0.79–13.19); P = 0.104
OR 2.44 (0.79–7.53); P = 0.122
OR 1.80 (0.52–6.22); P = 0.353
OR 1.80 (0.56–5.74); P = 0.320
OR 1.47 (0.48–4.53); P = 0.502
OR 0.65 (0.38–1.11); P = 0.116
10⁰
10¹
10²
Odds ratio for perioperative MACE (log scale, 95% CI)

Fig. 4.

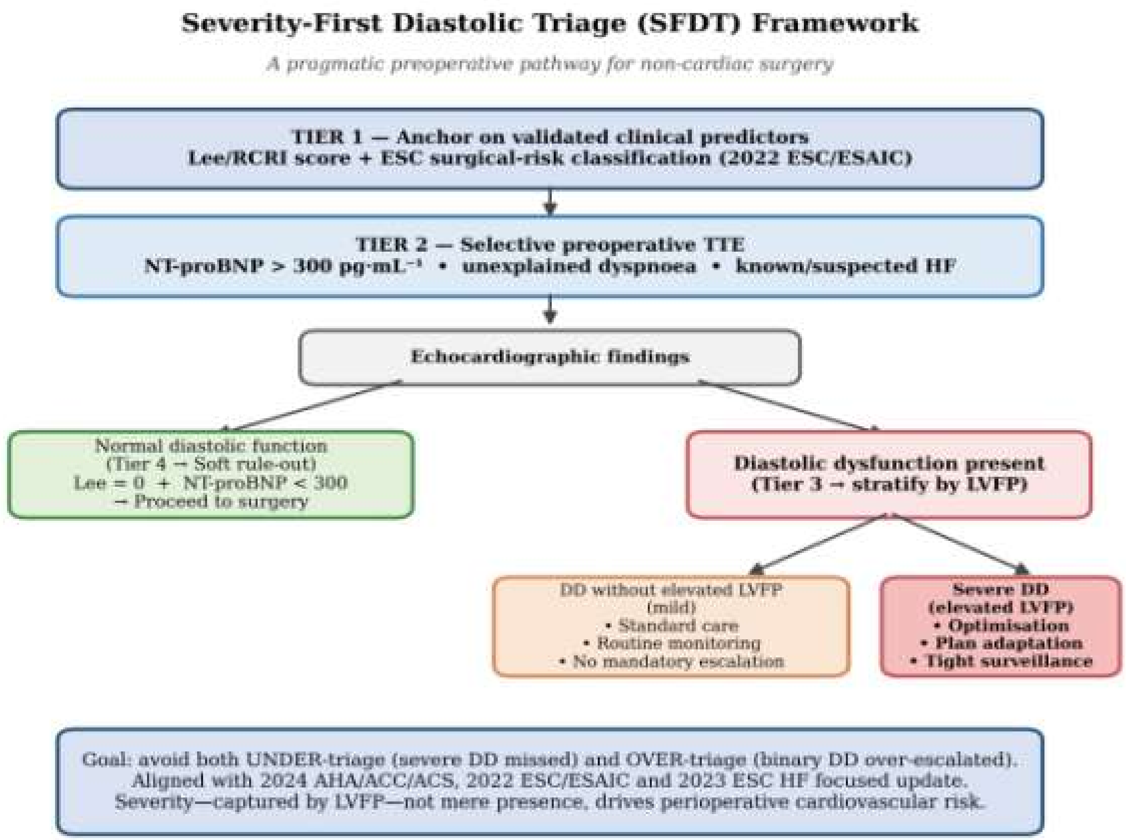

Severity-First Diastolic Triage (SFDT) Framework
A pragmatic preoperative pathway for non-cardiac surgery
TIER 1 — Anchor on validated clinical predictors
Lee/RCRI score + ESC surgical-risk classification (2022 ESC/ESAIC)
TIER 2 — Selective preoperative TTE
NT-proBNP > 300 pg·mL⁻¹ • unexplained dyspnoea • known/suspected HF
Echocardiographic findings
Normal diastolic function
(Tier 4 → Soft rule-out)
Lee = 0 + NT-proBNP < 300
→ Proceed to surgery
Diastolic dysfunction present
(Tier 3 → stratify by LVFP)
DD without elevated LVFP
(mild)
• Standard care
• Routine monitoring
• No mandatory escalation
Severe DD
(elevated LVFP)
• Optimisation
• Plan adaptation
• Tight surveillance
Goal: avoid both UNDER-triage (severe DD missed) and OVER-triage (binary DD over-escalated).
Aligned with 2024 AHA/ACC/ACS, 2022 ESC/ESAIC and 2023 ESC HF focused update.
Severity—captured by LVFP—not mere presence, drives perioperative cardiovascular risk.

Fig. 5.

Discussion:-

This prospective cohort study yields four findings that together motivate a reframing of preoperative diastolic assessment in non-cardiac surgery. First, isolated DD with preserved LVEF affects more than half of LVEF-preserved patients (55%)—a much higher prevalence than implied by current guideline texts [11,12]. Second, it carries a robust biochemical and clinical signature: a 7-fold higher median NT-proBNP and a marked excess of diabetes, hypertension, and prior cardiovascular disease, consistent with subclinical HFpEF [1,2]. Third, its independent prognostic contribution to in-hospital MACE is, in fact, modest: as a binary predictor, it adds no incremental discrimination over Lee + NT-proBNP. Fourth, and decisively, severity—captured by elevated LVFP—does carry a clinically meaningful prognostic signal, lifting model AUC from 0.70 to 0.77.

Our findings sit coherently within the most recent evidence base. The 2024 AHA/ACC/ACS perioperative guideline [11] explicitly notes that abnormal left ventricular systolic or diastolic function is associated with increased perioperative MACE, but that the incremental value of NT-proBNP beyond risk indices and self-reported functional capacity is small [18]. Our results extend this view: when DD is treated as binary, the incremental signal disappears almost completely, mirroring the discrimination ceiling reported for binary biomarker dichotomies. The Fayad et al. [14] systematic review and meta-analysis reported a pooled OR of approximately 1.7 for any DD and MACE—an effect that is real but small. Higashi et al. [27] showed that an E/e′ ≥ 15 (i.e., a severity criterion) tripled the risk of postoperative heart failure in intermediate-risk surgery, again consistent with severity—not presence—as the operative dimension.

In the broader cardiology literature, DD severity has emerged as the dominant prognostic vector. The 2023 ESC focused update on heart failure [20] elevated sodium–glucose cotransporter-2 (SGLT2) inhibitors (dapagliflozin or empagliflozin) to a Class IA recommendation across the entire LVEF spectrum, including HFpEF, on the basis of the EMPEROR-Preserved and DELIVER trials [32,33]. Recent network meta-analyses confirm convergent benefit of SGLT2 inhibitors on cardiovascular death and heart-failure hospitalization in mildly reduced and preserved ejection fraction [28,47]. Although these therapies are not deployed perioperatively, they reframe the natural history we are trying to interrupt: preoperative isolated DD is not just an echocardiographic finding but a prognostic entry point into a treatable trajectory.

Recent imaging work also resonates with our central message. The SOLOMON study [19] showed that preoperative left ventricular global longitudinal strain modestly improved MACE prediction in non-cardiac surgery patients—consistent with our finding that more granular indices of myocardial function add value where binary classifications saturate. Meta-analyses of left atrial reservoir strain [29] support its prognostic role in HFpEF and across surgical cohorts, suggesting a future axis for refining the severity gradient.

Our emphasis on biomarker-anchored, severity-weighted triage is also consistent with a broad perioperative literature. Preoperative and postoperative natriuretic peptides and high-sensitivity cardiac troponin have repeatedly predicted major adverse cardiovascular events and mortality after non-cardiac surgery [34–38,40]; perioperative myocardial injury and hypotension are strongly linked to downstream events and hospital readmission [39,41]; and transthoracic echocardiography and self-reported functional capacity remain complementary tools within a structured preoperative evaluation [42–44]. Against this backdrop, our observation that binary DD adds little beyond the Lee score and NT-proBNP—whereas DD severity does—supports a parsimonious, severity-weighted use of preoperative echocardiography rather than its indiscriminate application [45,46].

On the basis of our data and the broader literature, we propose a pragmatic preoperative algorithm for non-cardiac surgery, which we term Severity-First Diastolic Triage (SFDT) (Fig. 5):

- Tier 1—Anchor on validated clinical predictors. Compute the Lee/RCRI score and identify high-risk surgery as defined by 2022 ESC criteria [12]. These two variables retain by far the strongest independent association with MACE in our and others' data.
- Tier 2—Reserve preoperative TTE for selected patients. Restrict routine preoperative echocardiography to patients with NT-proBNP > 300 pg/ml, unexplained dyspnea, or known/suspected heart failure—as already implied by the 2024 AHA/ACC [11] and 2022 ESC/ESAIC [12] guidelines, which discourage indiscriminate preoperative TTE.
- Tier 3—Stratify by DD severity, not its binary presence. When TTE is performed, classify diastolic function not only as present/absent but along the LVFP gradient. Isolated DD without elevated LVFP confers a small absolute MACE excess that does not justify systematic escalation; isolated DD with elevated LVFP markedly elevates risk and warrants preoperative cardiovascular optimization, anesthetic plan adaptation (cautious volume

management, avoidance of tachycardia, appropriate intraoperative monitoring), and intensified postoperative surveillance.
- Tier 4—Use the absence of DD as a soft rule-out. The 83% negative predictive value of isolated DD alone (combined with Lee = 0 and NT-proBNP < 300 pg/ml) supports straightforward progression to surgery without further cardiac testing in the lowest-risk LVEF-preserved patients—aligning with the parsimony favored by the 2024 AHA/ACC update [11].

This framework moves the conversation from "is there DD?"—a binary that drives both over-triage and under-triage—to "how severe is the DD, and what does it mean alongside Lee and NT-proBNP?". The full proposed algorithm is summarized in Fig. 5. Our 5-fold higher rate of preoperative therapeutic adjustments in isolated-DD patients (50.0% vs. 11.1%) reveals an outcome paradox: clinicians already act on DD even when its independent prognostic value is small, and that pre-emptive action may itself attenuate the MACE difference observed at the bedside [30]. This is not an argument against assessment but for targeted assessment: when a common finding prompts pre-emptive correction in many patients, it can dilute its own measurable effect on outcomes. The SFDT framework formalizes this insight.

Pathophysiologically, the strong association of isolated DD with diabetes, hypertension, and elevated NT-proBNP places these patients on the HFpEF continuum [1,2,31]. The preoperative consultation thus becomes an unrecognized case-finding opportunity: identification of severe DD before surgery flags a population in whom postoperative initiation of guideline-directed HFpEF therapy (SGLT2 inhibitors per the 2023 ESC update [20]) may have benefits well beyond the immediate perioperative window—a hypothesis worth testing in interventional trials.
Strengths include the prospective design, consecutive enrollment, blinded echocardiographic assessment by a single experienced operator using current 2016 ASE/EACVI criteria, complete preoperative biomarker capture, and adjudicated outcomes. Reporting follows the STROBE and TRIPOD statements.

Several limitations deserve frank acknowledgment. First, the modest sample size (n = 80 in the primary comparison) and the limited number of MACE events (n = 16) leave the study underpowered to detect small-to-moderate independent effects of binary isolated DD. The non-significance of isolated DD as a MACE predictor (P = 0.502) should be interpreted as absence of evidence, not evidence of absence. Second, single-center recruitment limits external generalizability, particularly across surgical case-mix and ethnic backgrounds. Third, the in-hospital composite endpoint mixes events of heterogeneous severity; longer-term outcomes (30-day, 90-day, and 1-year MACE and mortality) were not captured. Fourth, although the operator was blinded, single-reader echocardiographic interpretation introduces residual variability; multi-reader designs incorporating global longitudinal strain and left atrial strain would strengthen future iterations. Fifth, high-sensitivity cardiac troponin—now Class I in the 2022 ESC/ESAIC and 2024 AHA/ACC guidelines [11,12]—was not systematically measured; its joint use with NT-proBNP and LVFP merits prospective study.

The SFDT framework requires external validation. Four research priorities follow:-
- A multicenter prospective validation cohort (≥ 500 patients) powered to confirm the incremental prognostic value of LVFP—not binary DD—over Lee + NT-proBNP, with longer follow-up (30-day and 1-year MACE).
- Integration of advanced echocardiographic markers—global longitudinal strain and left atrial reservoir strain [19,29]—as continuous severity indices, potentially replacing the categorical LVFP threshold.
- A randomized pragmatic trial of "targeted TTE plus protocolized optimization" versus standard care in NT-proBNP-positive patients, with hard cardiovascular outcomes.
- Implementation studies of SFDT-guided preoperative pathways with health-economic outcomes (cost per MACE prevented, cardiology consultation rate, surgical-cancellation rate).

Conclusion:-
More than half of LVEF-preserved patients undergoing elective non-cardiac surgery have isolated diastolic dysfunction. As a binary echocardiographic finding, isolated DD adds little to the prognostic discrimination already achieved by the Lee score and NT-proBNP. Its severity—operationalized as elevated left ventricular filling pressures—does carry a clinically meaningful incremental signal. Preoperative diastolic assessment should therefore move from a binary alarm to a graded triage that integrates the Lee score, NT-proBNP, and LVFP. The Severity-First Diastolic Triage framework operationalizes this shift and offers a pragmatic, guideline-aligned pathway to rationalize preoperative decision-making in non-cardiac surgery.

Conflicts of interest:-No potential conflict of interest relevant to this article was reported.

Funding:-This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Ethics approval and consent to participate:-The study protocol was approved by the institutional ethics committee (Comité d'Ethique pour la Recherche Biomédicale, Université Mohammed V, Rabat; approval number 31/25) and complied with the Declaration of Helsinki (revised 2013). Written informed consent was obtained from every participant prior to inclusion.

Data availability:-The anonymized individual participant data and the analytic code that support the findings of this study are available from the corresponding author upon reasonable request, subject to approval by the local Institutional Review Board.

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