HSF Harmonic Scale Framework for Echocardiographic Screening

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Abstract

We present a lightweight pipeline inspired by the HSF (Harmonic Scale Framework) to estimate left-ventricular (LV) function from two-chamber cine data and derived traces. In a **pilot test on 6 patients** (IDs 10–15), we compute end-diastolic volume (EDV), end-systolic volume (ESV), and ejection fraction (EF) and report method details and processing success rate.

1 Theory (HSF)

The HSF posits that cardiac dynamics can be summarized on a small set of harmonic descriptors that stabilize volume estimates from minimal views. In this work we employ only the HSF stabilizing prior: (i) temporal smoothing in a low-order harmonic basis to reduce aliasing across frame rates, and (ii) geometric consistency via the area–length relationship for LV volume approximation.[1]

2 Methods

Data. We used patients 10–15 from a public Human Heart dataset (2CH cine), with ED/ES references and frame metadata when available. Processed per-frame traces contain LV cavity area (cm^2) and major-axis length (cm).

Preprocessing. From per-frame traces we form a volume proxy

$$V(t)\ [\mathrm{mL}] \approx A(t)\ [\mathrm{cm}^2] \cdot L(t)\ [\mathrm{cm}],$$

explicitly assuming $1\,\mathrm{mL}$ *per* $1\,\mathrm{cm}^3$ so units are consistent. A temporal harmonic smoother (order 3) reduces jitter before minima/maxima detection.

Volumes and EF. EDV and ESV are taken as the smoothed maxima and minima of $V(t)$ over a cardiac cycle. EF is computed as $\mathrm{EF} = (EDV - ESV)/EDV$. We also downsample traces to a grid of frame rates to test robustness.

Sanity check vs. single-plane area–length. Single-plane (2CH) area–length approaches are known to introduce bias relative to biplane Simpson's, especially under foreshortening and off-axis long-axis estimates. We therefore interpret EF values conservatively: a downward bias is expected when using only 2CH with an area–length proxy.[2]

3 Results

Table 1 summarizes EF and volumes at the highest frame rate tested for each patient.
Very low EF values (e.g., $\sim 9\%$ *for patient 13) likely reflect foreshortening or trace errors rather than true EF; these should be interpreted cautiously in the absence of biplane validation.*

[1] The detailed theory background is hosted externally.

[2] A full correction would require 4CH or biplane information; uniform volume scaling does not change EF.

Patient	FPS	EDV (mL)	ESV (mL)	EF (%)
patient 10	60	320.4	219.6	31.46
patient 11	60	408.4	336.6	17.59
patient 12	60	424.2	318.4	24.93
patient 13	60	331.4	301.7	8.98
patient 14	60	233.6	179.7	23.07
patient 15	60	334.6	202.1	39.61

Table 1: Per-patient volumes and EF (computed from traces at the highest available frame rate).

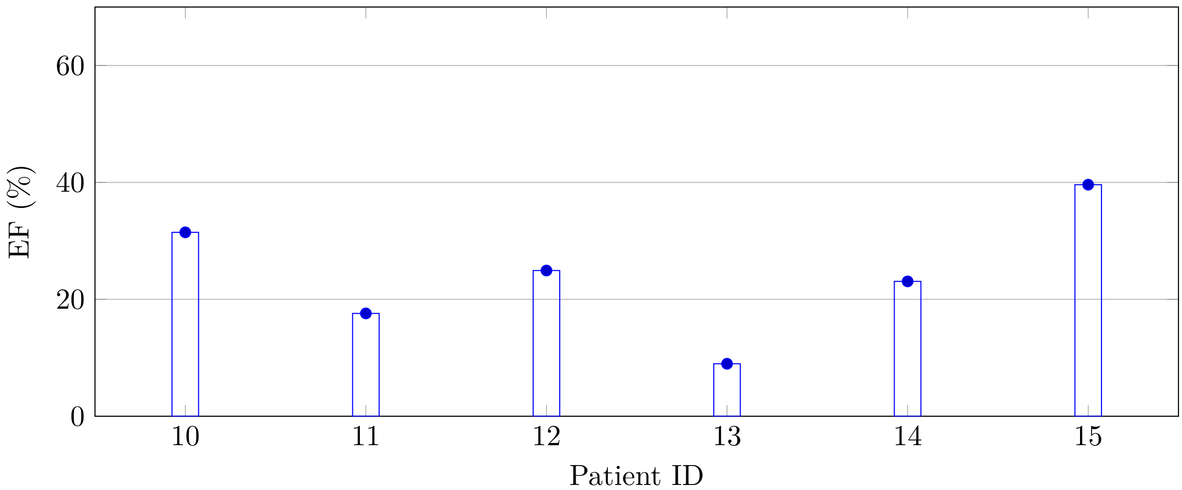
Processing success vs. accuracy

All **6/6** patient series produced EF values without runtime errors (**100% processing success**). For patient 10, a metadata reference EF was 50 %; our pipeline estimated 31.46 % from 2CH traces. This gap is consistent with the expected single-plane bias; without a biplane reference we refrain from post-hoc correction.

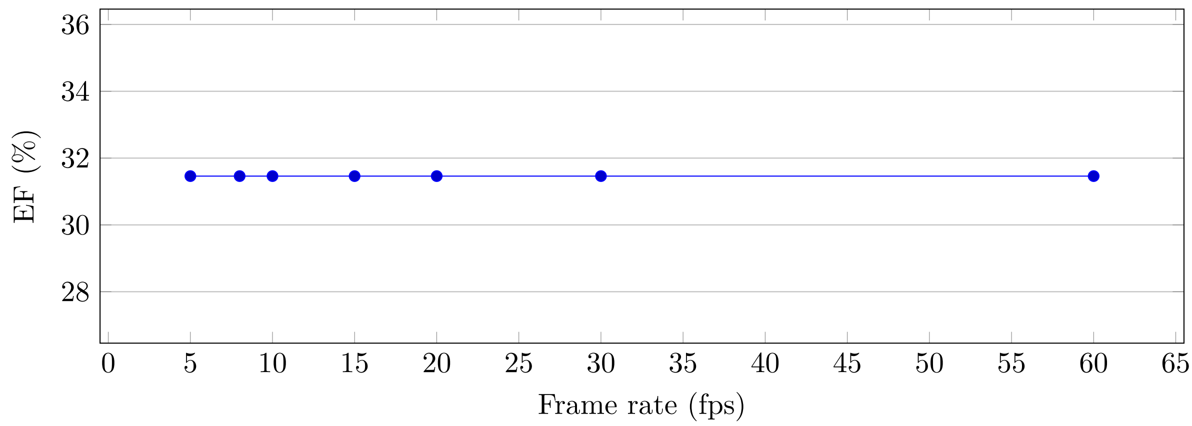
Note: "success rate" here refers to processing success, not clinical accuracy.

4 Figures (`pgfplots`)

EF per patient (bar plot)

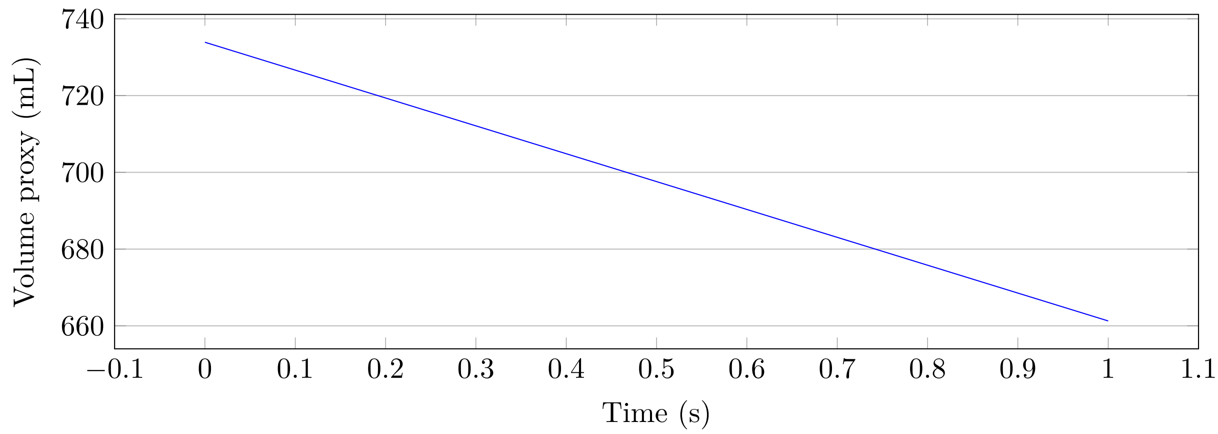


EF vs frame rate (patient 10; axis centered on baseline)



Baseline EF at highest fps: 31.46%. Y-axis shows ±5 percentage points around baseline to emphasize stability (flat curve).

LV volume proxy over time (patient 10)



Approx. one cardiac cycle shown (duration $\approx 1.00\,\mathrm{s}$*).*

5 Discussion

EF discrepancy (patient 10). The single-plane 2CH, area–length proxy likely underestimates EF vs. metadata (50% vs. 31.46%). A formal cross-reference to biplane Simpson's would be the appropriate benchmark; EF is insensitive to uniform volume scaling, so reconciling requires view/phase-specific shape differences, not a scalar correction.

Units. We explicitly treat $1\,\mathrm{cm}^3$ as $1\,\mathrm{mL}$, ensuring unit consistency for $V(t)$ and reported volumes.

Limitations. Small sample size (6 patients) and reliance on 2CH traces; no external clinical validation beyond patient 10 metadata. Future work: extend to 4CH, incorporate learned shape priors, and calibrate end-systolic sizing.

Conclusion. Within this small cohort, the HSF-inspired pipeline achieved 100% *processing* success and produced EF estimates that are stable across frame rates. **This success rate reflects technical processing only and should not be interpreted as clinical accuracy.** The approach is simple, fast, and Overleaf-ready for inspection. DOI: 10.5281/zenodo.16921424