

STARLING PUBLISHED STUDIES

- OVER 100 PEER REVIEWED PUBLICATIONS
- MULTIPLE CLINICAL SETTINGS (ICU/OR/ED/EXERCISE LAB/OUTPATIENT)
- COMPARATIVE ANALYSES AGAINST ALL MAJOR TECHNOLOGIES, INCLUDING SWAN GANZ, PULSE CONTOUR, DOPPLER AND FICK

VALIDATION

Starling is the only non-invasive monitor that has been successfully compared to thermodilution in multiple clinical settings.

Rich, J et al. Noninvasive cardiac output measurements in patients with pulmonary hypertension. *Eur Respir J.* 2013;42:125-33.

- 50 consecutive patients with Pulmonary Hypertension receiving a right heart catheterization were also monitored with **Starling** and indirect Fick.
- The study showed that the **Starling** had improved accuracy and precision than Thermodilution compared to the Fick.
- **Starling** accurately detected directional changes to a vasoactive medication administration.

Heerdt PM et al. Noninvasive cardiac output monitoring with bioreactance as an alternative to invasive instrumentation for preclinical drug evaluation in beagles. *J Pharmacol Toxicol Methods.* 2011;64:111-8.

- **Starling** algorithm was compared to an Aortic Flow Probe in beagles. Aortic Flow Probe is the gold standard in measuring flow.
- In over 516 distinct measurements the **Starling** exhibited high accuracy and precision when compared with the aortic flow probe
- This study also highlights the algorithm's ability to handle low flow states:
 - Accuracy compared to Flow Probe: **Starling** 95%
 - Precision (bias) compared to Flow Probe: **Starling** 6.1% vs. Flow Probe 0.8%
 - Sufficient fidelity to detect and quantify acute, drug induced, directional changes in CO

FLUID MATTERS

IV FLUIDS CAN CAUSE HARM...

- Fluid is an independent predictor of mortality (Marik, 2017)
- Only ~50% of hemodynamically unstable patients will respond to IV fluid by increasing cardiac output and perfusion (Bentzer, 2016)
- Assessing whether fluid may help or harm a patient is a critical step in optimizing treatment.

Bentzer P et al. Will this hemodynamically unstable patient respond to a bolus of intravenous fluids? *JAMA*. 2016;316:1298-309.

- Meta-analysis evaluating over 50 studies (2260) patients looking tests to predict fluid responsiveness. This is the largest fluid responsiveness analysis to date.
- Summary fluid responsiveness is 50% (95% CI 42% to 56%). The study evaluates physical exam, CVP, Pulse Pressure Variation, IVCc, ECHO, Cardiac Output / Stroke Volume to assess fluid responsiveness
- Physical exam and CVP cannot be used to reliably predict fluid responsiveness.
- Pulse Pressure, SV Variation, IVCc work in very limited clinical conditions (require controlled ventilation).
- SV change was the best predictor of fluid effectiveness (Sensitivity 88%, Specificity 92%).

Marik PE et al. Fluid administration in severe sepsis and septic shock, patterns and outcomes: an analysis of a large national database. *Intensive Care Med*. 2017;43(5):625-32.

- In this Premier database analysis, 23,513 patients with severe sepsis and septic shock were admitted to ICU from the ED.
- Day 1 fluid averaged 4.4L, and for each liter over 5L, mortality increased by 2.3%, and added \$999 treatment cost.
- Even the small difference of 600cc can increase the patient's risk.

ASSESSING FLUID RESPONSIVENESS

Marik PE et al. The use of bioimpedance and carotid Doppler to determine volume responsiveness and blood flow redistribution following passive leg raising in hemodynamically unstable patients. *Chest*. 2013; 143(2):364-70.

- The study demonstrated that a PLR maneuver using the **Starling** provides an accurate method of assessing volume responsiveness in critically ill patients.
- PLR results (SV>10%=Fluid Responsive) were compared to Carotid Doppler in 34 hemodynamically unstable patients.
- The PLR maneuver had a sensitivity of 94% and a specificity of 100% for predicting volume responsiveness (one false negative).
- **Starling** is the only non-invasive technology with a validation study evaluated during the PLR.

CLINICAL AND FINANCIAL OUTCOMES

Latham H et al. Stroke volume guided resuscitation in severe sepsis and septic shock improves outcomes. *J Crit Care.* 2017;28:42-46.

- Retrospective matched, single-center study, SV group comprised 100 patients, with 91 patients in the UC group.
- The study concluded that optimized fluid management in patients with severe sepsis and septic shock may lead to improved clinical outcomes.
 - Reduced Fluid Balance and reduced time on Pressors
 - Reduced Length of Stay (2.89 Days)
 - Decreased need for Mechanical Ventilation (25%) and Acute Dialysis (13.25%)

Variable	Starling Stroke Volume Fluid Therapy (n=100) ¹	Usual Care (Control, n=91) ¹	Δ/p Value ¹	Costs Assumptions*	Cost Avoidance*
ICU LOS (Days)	5.98 ± 0.68	8.87 ± 1.18	2.89 days P = 0.03	\$4,004/ICU day ² \$906/floor day ³	\$8,953
Fluid Balance (Liters)	1.77 L ± 0.60	5.36 L ± 1.01	3.59 L P = 0.002		
Pressor Use (Hours)	32.08 ± 5.22	64.86 ± 8.39	32.78 hours P = 0.001		
Mechanical Ventilation (Relative Risk)	29%	57%	RR=0.51 P = 0.001	\$1,522/day ⁴ 5.1 days ³	\$1,940
Acute Dialysis Therapy Initiated	6.25%	19.5%	13.25% P = 0.01	\$27,182 x (lc) (12.73 cases avoided/ 96 total patients) ³	\$3,605
ESTIMATED SAVINGS PER TREATED PATIENT*					\$14,498

*Based upon supplemental data.

COST ASSUMPTIONS

ICU Length of Stay (LOS): 2.89 days x [\$4,004 [Avg ICU Day] – \$906 [Avg Floor Day]] = \$8,953

Mechanical Ventilation (MV): \$1,522 x 5.1 days x .25 = \$1,940

Assumes:

1. Incremental cost of MV \$1,522/day. 2. Average duration of MV in septic shock 5.1 days. 3. Assumes an absolute 25% reduction of patients receiving mechanical ventilation.

Acute Dialysis Therapy: \$27,182 (avg. dialysis-related hospital costs) x (12.73 cases avoided/96 total patients) = \$3,605

REFERENCES

1. Latham H, et al. Stroke volume guided resuscitation in severe sepsis and septic shock improves outcomes. *J Crit Care.* 2017;28:42-46.
2. Huynh T, et al. The frequency and cost of treatment perceived to be futile in critical care. *JAMA Internal Med.* 2013;173.
3. Premier Data Set, 2013. Premier, Inc.
4. Dasta JF, McLaughlin TP, Mody SH, Piech CT. Daily cost of an intensive care unit day: The contribution of mechanical ventilation. *Crit Care Med.* 2005;33(6):1266-1271.

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