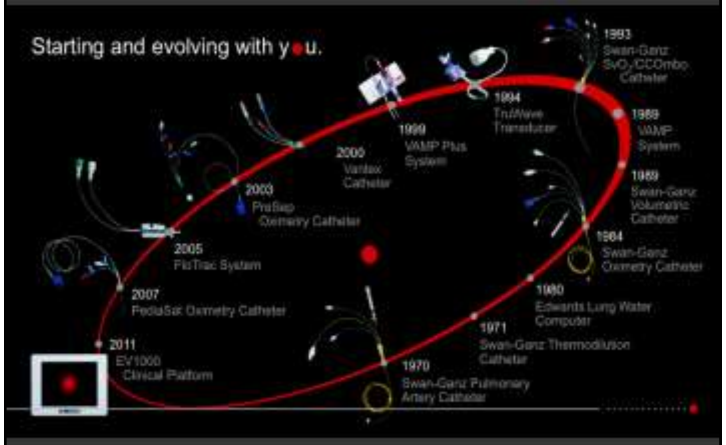
Covenant Healthcare Respiratory Care Conference

Hemodynamic Monitoring

Nancy Hearold RN CCRN CFS III

Disclosures

- Employed by Edwards Lifesciences as their Critical Care Field Specialist.
- Patient advocate !!



OBJECTIVES

- Hemodynamic Simulated Cases
- Talk about Reactive vs Proactive Treatment
- Pressure vs Flow / Static vs Dynamic
- SV Optimization through Simulations & Live Demo
- Parameters and technologies
- Recap Q & A and Resources

Resources for you

- Free iPhone/iPad app
  - Search: *"Edwards Critical Care"*
- Two YouTube Channels
  - hemodynamicmonitor1
  - ecce4you
- www.edwards.com/cceducation
- Nancy Hearold 586-651-1671
- Nancy_hearold@edwards.com

HEMODYNAMIC MONITORING

Proactive VS Reactive

Can more information help us from guessing and reacting ?

Less and non invasive technologies can allow us to be proactive vs reactive

Traditional measures… Are they enough??

MAP: slow to respond, does not tell the full story…

"It should be recognized that systemic hypo-perfusion usually precedes hypotension, especially in patients with sepsis." Rackow, JAMA 1991

"The most rudimentary measure used to assess fluid responsiveness is the mean arterial pressure (MAP), but this value alone provides little useful information regarding actual blood flow or oxygen delivery. Anesth Analg., 2005

Assumptions:

- Blood Pressure reflects flow
- MAP = CO
- If BP goes up… then CO goes up
- If CO is down… then BP is down

Assumption P=F

is really a

MISCONCEPTION

Traditional measures… Are they enough??

*"Although vital signs help assess the adequacy of **tissue perfusion**, they are a **late indicator** of tissue ischemia."*

HR MAP Spo2 UO

ScV02 CO/CI SVV SV/SVI SVR/SVRI

"Analysis of hemodynamic variables beyond traditional measures allows the clinician to differentiate various causes of hemodynamic instability and intervene appropriately...."

The *FloTrac* sensor… why should I use it?

- SV= Stroke Volume
- SVI= Stroke Volume Index
- CO= Cardiac Output
- CI=Cardiac Index
- SVR= Systemic Vascular Resistance
- SVRI=Systemic Vascular Resistance Index
- SVV= Stroke Volume Variation
- ScV02= Central Venous Oxygenation

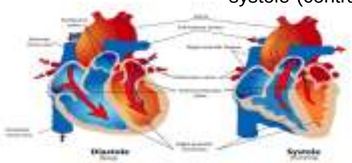
- **SV= Stroke Volume**
  - The amount of blood pumped by the left ventricle of the heart in one contraction.
  - Normal Range 60-100 ml/beat
  - The stroke volume is determined by the preload, afterload, and contractility of the ventricle.
- **SVI= Stroke Volume Index**
  - Stroke Volume divided by the body surface area (BSA).
  - Normal Range 33-47 ml/beat/m2

Stroke Volume

SV = EDV - ESV

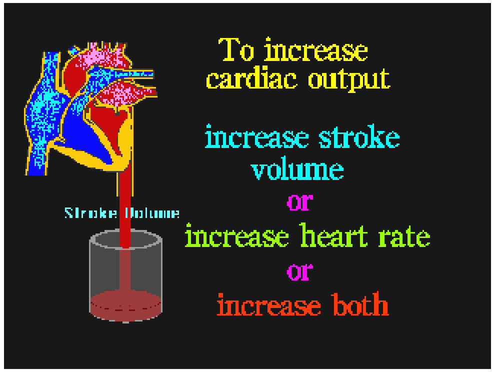
End Diastolic Volume (EDV): The amount of blood that has filled the left ventricle during diastole.

End Systolic Volume (ESV): The amount of blood that is remains in the ventricle after systole (contraction).



Normal SV 60 – 100 ml/beat
Normal SVI 30 – 50 ml/beat/m²

Hemodynamics Review



- **CO= Cardiac Output**
  - The amount of blood that is pumped by the heart per unit time, measured in liters per minute (l/min).
  - Normal Range 4.0-8.0 L/min
- **CI=Cardiac Index**
  - Cardiac output divided by the body surface area (BSA).
  - Normal range 2.5-4.0 L/min/m2

- **SVR= Systemic Vascular Resistance**
  - A measure of arteriolar constriction or dilation throughout the body, calculated by dividing the blood pressure by the cardiac output
  - Normal Range 800-1200 dynes-sec/cm-5
- **SVRI=Systemic Vascular Resistance Index**
  - SVR divided by the body surface area (BSA).
  - Normal Range 1970-2390 dynes-sec/cm-5/m2

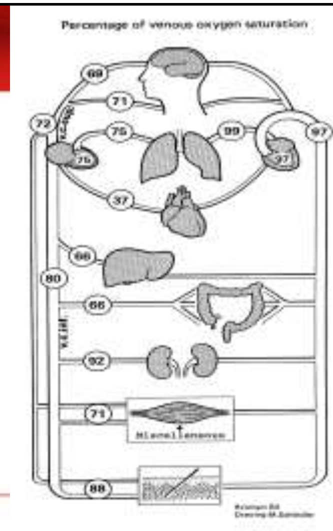
Hemodynamic Math Review

Cardiac Output = **Heart Rate (PR) x Stroke Volume**

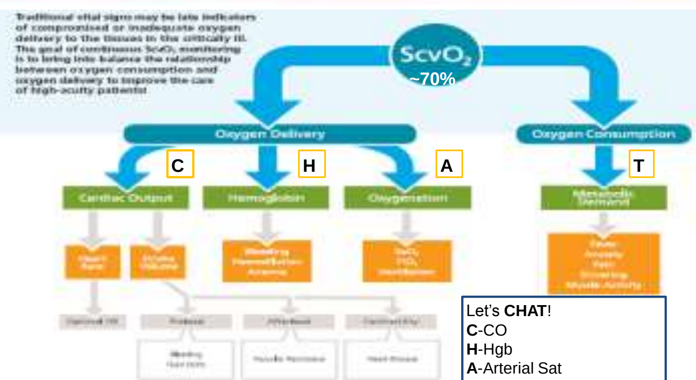
Venous Oximetry

- Global
- Regional
- Organ specific

PA - Mixed Venous Blood (SvO_2)	60-80%
SVC ($ScvO_2$)	70%
IVC	80%
Coronary Sinus	37%
Jugular bulb (SjO_2)	55-65%



ScvO2 Algorithm



Let's **CHAT**!
C-CO
H-Hgb
A-Arterial Sat
T-Tissue Demands

DO_2 is usually more than needed, unless….

consumption increases beyond delivery, or tissues are unable to extract oxygen

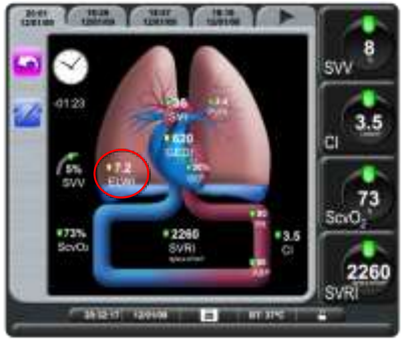
Factors increasing % of V02

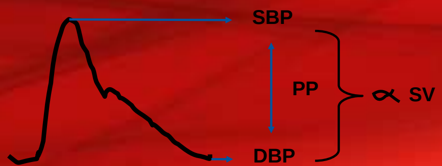
Non-sedated head injury	138%
Burns	100%
Sepsis	50 - 100%
Shivering	50 - 100%
MODS	20 - 80%
Work of breathing	40%
Weighing patient	36%
Changing position	31%
Suctioning	27%
CXR	25%
Bath	23%
Fever, Dressing change	10%

Curley & Maloney-Harmon

EVLW

Extra Vascular Lung Water

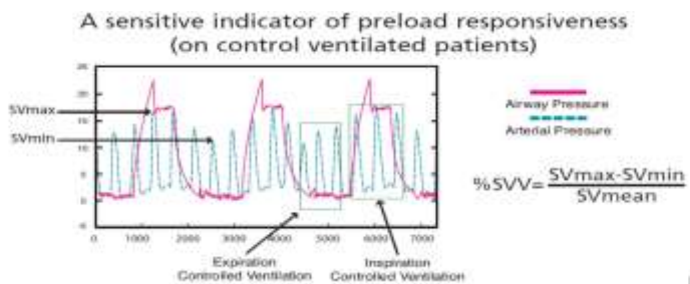




Pulse pressure (SBP – DBP) is proportional to Stroke Volume.

SV x PR = CO

Stroke Volume Variation literally is a calculated percentage of variation between the Stroke Volumes…



Two Major Indications of SVV:

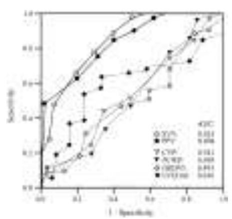
- 1. evaluate the response to fluid interventions
- 2. determine or *predict* the patient's potential response to fluid therapy
- If variability is low, need for fluid low
- If variability is high, need for fluid is high

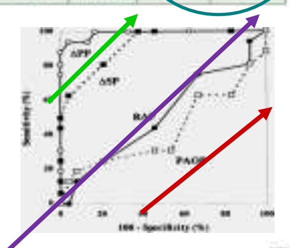
Limitations of SVV.. and only SVV!!

- Mechanical Ventilation
  - Currently, literature supports the use of SVV on patients that are 100% mechanically (control mode) ventilated with tidal volumes ≥ 8cc/kg and fixed respiratory rates.
- Spontaneous Breathing
  - Unless taking regular rate, and adequate tidal volumes…
- Arrhythmias
  - Previously, arrhythmias dramatically affected SVV. However, early 2012 software upgrade able to filter out arrhythmias
    (6 PVCs per 20 sec)
    Icon indicates too much cardiac variability

Preload Responsiveness: SVV

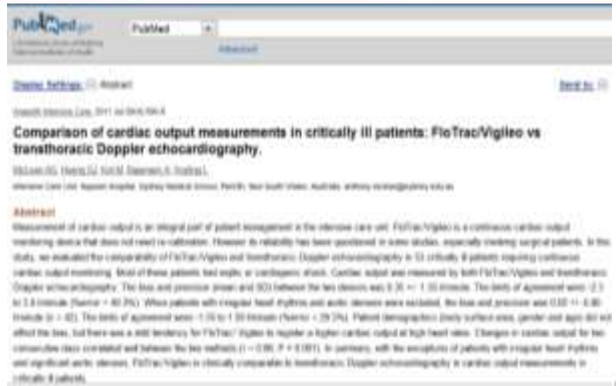
Study	Patients	Volume	Tidal Volume ml/Kg	R^2	Def. of Responder	Sensitivity	Specificity
Michard[6]	Sepsis	500 ml	8 to 12	0.85	ΔCO≥15%	94	96
Berkenstadt, et al.[7]	Neuro Surgery	100 ml	10	0.53	ΔSVI≥5%	79	93
Reuter, et al.[8]	Cardiac	10 x BMI	10	0.64	ΔSV≥5%	79	85





Predicting SVI changes >= 25%, CI > *Hofer, 2005 & Michard 1999*

Validation of FloTrac CO measurement with TEE



What is *Stroke Volume Variation*??

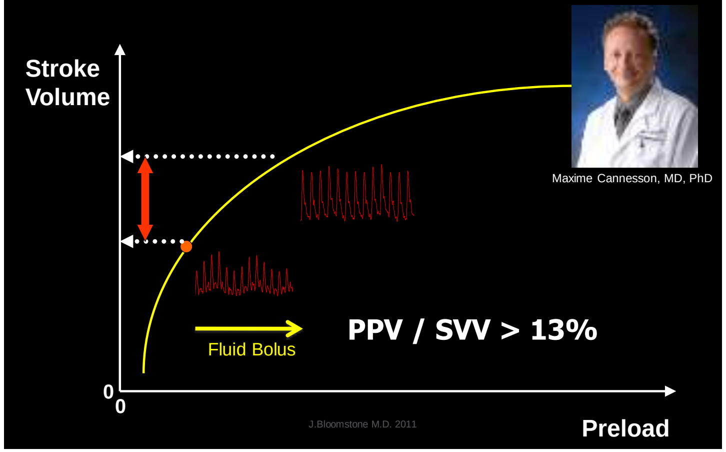
Stroke Volume Variation Animation

http://www.youtube.com/watch?v=ew0H6eTrt90&feature=plcp

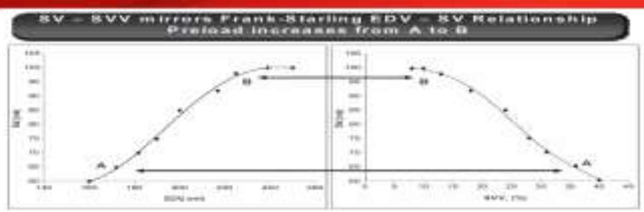
Conceptually…

Journal of Cardiothoracic and Vascular Anesthesia, Vol 24, No 3 (June), 2010: pp 487-497

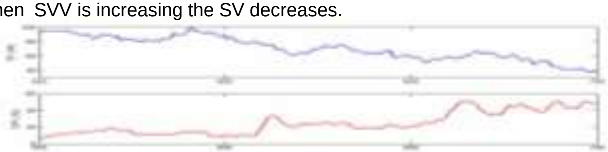
Preload Dependence Optimization Concept



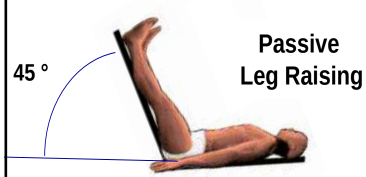
SVV relationship to SV: The Dynamic Duo



Trend over time of SV and SVV. Note that when the SV is high the SVV is low. When SVV is increasing the SV decreases.



PLR Or Fluid Challenge



SVI

- 150 – 300 ml volume
- Effects < 30 seconds Not more than 4 minutes
- Self-volume challenge
- Physiologic Fluid Challenge
- Reversible

Stroke Volume Optimization

- Normal SV is 60 – 100. It has an inverse relationship with SVV. When the patient is dry the SV decreases
- Normal SVI is ~ 30 - 50

Validation of SV changes with TEE for predicting fluid responsiveness

Research

Open Access

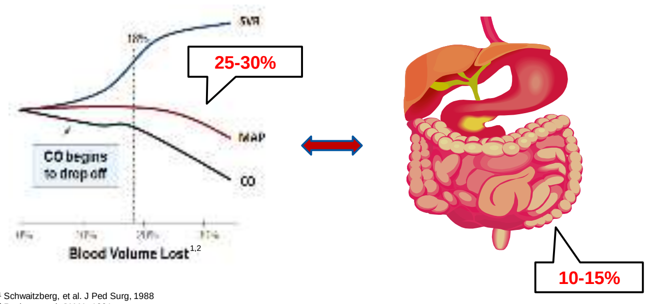
Changes in stroke volume induced by passive leg raising in spontaneously breathing patients: comparison between echocardiography and Vigileo™/FloTrac™ device

Matthieu Biais, Lionel Vidil, Philippe Sarrabay, Vincent Cottenceau, Philippe Revel and François Sztark

Results Four patients were excluded. No patients received vasoactive drugs. Seven patients presented septic hypovolemia. PLR-induced changes in SV-TTE and in SV-Flotrac were correlated ($r^2 = 0.56$, $P < 0.0001$). An increase in SV-TTE ≥ 13% during PLR was predictive of response to volume expansion with a sensitivity of 100% and a specificity of 80%. An increase in SV-Flotrac ≥16% during PLR was predictive of response to volume expansion with a sensitivity of 85% and a specificity of 90%. There was no difference between the area under the ROC curve for PLR-induced changes in SV-TTE (AUC = 0.96 ± 0.03) or SV-Flotrac (AUC = 0.92 ± 0.05). Volume expansion-induced changes in SV-TTE correlated with volume expansion-induced changes in SV-Flotrac ($r^2 = 0.77$, $P < 0.0001$). In all patients, the highest plateau value of SV-TTE recorded during PLR was obtained within the first 90 s following leg elevation, whereas it was 120 s for SV-Flotrac.

Critical Care 2008, 12:R195 (doi:10.1186/cc7195)
This article is online at: http://ccforum.com/content/12/6/R195

Traditional fluid monitoring may be inadequate for moderate to high-risk patients



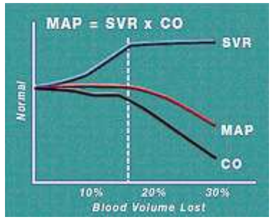
[1] Schwaitzberg, et al. J Ped Surg, 1988
[2] Rackow, et al. JAMA, 1991.
[3] Hamilton, et al. *Comparison of commonly used clinical indicators of hypovolaemia with gastrointestinal tonometry.* Intensive Care Med, 1997.

Fluid Challenge

Volume Challenge 250 or 500 ml
until SV or CO increase is less than 10%

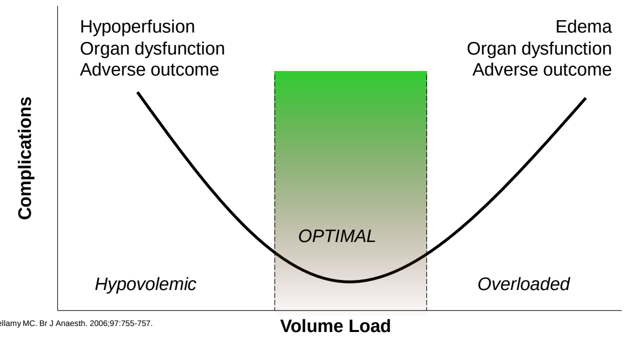
Inadequacy of Arterial Pressure

- Adequate pressure does not always mean adequate flow to tissues.
- Systemic hypo-perfusion usually precedes hypotension, especially in patients with sepsis.



Source: Schwaitzberg, *J Ped Surg* 1988; Rackow, *JAMA* 1991

Fluid imbalance leads to complications



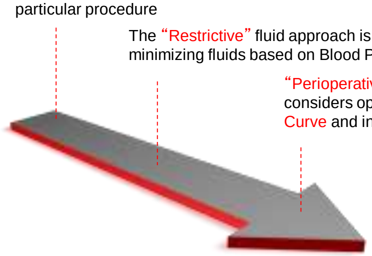
Bellamy MC. Br J Anaesth. 2006;97:755-757.

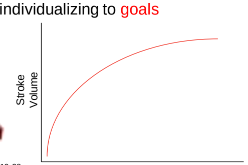
Volume management techniques are evolving

The "Conventional" approach is trying to predict the amount of volume / fluids needed based upon a the duration and severity of a particular procedure

The "Restrictive" fluid approach is based on minimizing fluids based on Blood Pressure

"Perioperative Goal-Directed Therapy " approach considers optimizing volume / fluids via the Frank-Starling Curve and individualizing to goals





Stolting et. al. Basics of Anesthesia, 5th ed. Elsevier - China, p. 349, 200
Michard F. Changes in arterial pressure during mechanical ventilation. Anesthesiology. 2005; 103: 419-28
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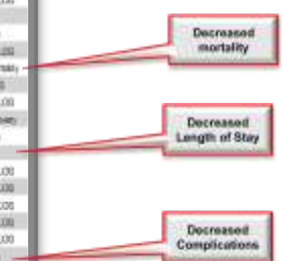
Improved Outcomes

Patients managed with goal-directed therapy have better outcomes[1-19]

Study (Year)	Goal	Surgery	Timing	Benefit
Shoemaker (1988)	DO_2>600	General	D + A	Complications, mortality
Boyd (1993)	DO_2>600	General	D + A	Complications, mortality
Mythen (1995)	SVmax with fluid	Cardiac	D	Complications, HLOS
Sinclair (1997)	SVmax with fluid	Hip	D	HLOS
Ueno (1998)	DO_2>600	Liver	D + A	Complications
Wilson (1999)	DO_2>600	General	D + A	Complications, HLOS
Lobo (2000)	DO_2>600	General	D	Complications, mortality
Pölönen (2000)	SVO_2>70% fluid, dobutamine	Cardiac	A	Mortality, HLOS
Gan (2002)	SVmax with fluid	General	D	Complications, HLOS
Venn (2002)	SVmax with fluid	Hip	D	Postoperative recovery
Conway (2002)	SVmax with fluid	Abdominal	D	Complications
McKendry (2004)	SVmax with fluid	Cardiac	A	HLOS
Pearse (2005)	DO_2>600	General	A	Complications, HLOS
Wakeling (2005)	SVmax with fluid	Abdominal	D	Complications, HLOS
Noblett (2006)	SVmax with fluid	Abdominal	D	Complications, HLOS
Donati (2007)	$ScvO_2$>73%	General	D + A	Complications, HLOS
Chytra (2007)	SVmax with fluid	Trauma	A	Complications, HLOS
Benes (2010)	SVV<10%	Abdominal	D	Complications
Cecconi (2011)	SVmax, DO_2>600 ml/min m^2	Hip	D	Complications



FloTrac System Outcome Studies
Validated to Improve Patient Outcomes

Author	Study Type	Benefit of Goal Directed Therapy
Benes et al	Optimizing SVV: High-Risk Patients Undergoing Major Abdominal Surgery	Reduced total complications by 56%
Ramsingh et al	Optimizing SVV: Low-Moderate Risk Patients Having Major Abdominal Surgery	Reduced length of stay by 28%
Cecconi et al	Optimizing SV: Hip Replacement Surgery	Reduced total complications by 71%
Donati et al	Optimizing $ScvO_2$ with PreSep oximetry catheter: Goal-directed Therapy in High-Risk Surgical Patients	Decreased organ failure by 67% Decreased length of stay by 16%

End Points

- **$ScvO_2$ 70%**
- **Sv02 60-80**
- **SV Individually Optimized**

- **SVV 9 – 10-15% Gray Normal (13%)**
- Watch the whole picture as CI/CO/SVR/SVI/UOP/HR all *react*

SVV and CVP Differential Diagnosis

Diagnosis	**SVV**	**CVP**
• **Hypovolemia**	**High**	**Low**
• **Hypervolemia**	**Low**	**High**
• Irregular Rhythm	**?**	**?**
• Cardiac Tamponade	**High**	**High**
• Constrictive Pericarditis	**High**	**High**
• Abdomenal Tamponade	**High**	**High**
• Tension Pneumothorax	**High**	**High**
• Right Sided Heart Failure	**High**	**High**

The Literature is Out There….

The evidence is clear

PGDT Evidence Base

- 30+ positive RCTs
- 9+ Meta-analyses
- Several QIPs

- 32-55% reduction in post-surgical complications[1,2]
- 1-2 days average reduction in length of stay[2,3]

[1] Hamilton M, Cecconi M, Rhodes A. A systematic review and meta-analysis on the use of preemptive hemodynamic intervention to improve postoperative outcomes in moderate and high-risk surgical patients. *Anesth Analg. 2011;112(6):1392-140*
[2] Grocott, et al. *Perioperative increase in global blood flow to explicit defined goals and outcomes after surgery: a Cochrane Systematic Review.* BJA, 2013.
[3] Corcoran et al. Perioperative Fluid Management Strategies in Major Surgery: A Stratified Meta-Analysis. Society of Critical Care Anesthesiologists. 2012 ; 114 (3)

Major colorectal complications

1. Time to feed (Ileus)
2. Surgical site infection
3. Urinary infection
4. DVT
5. Myocardial infarctions
6. Stroke
7. Post procedural delirium
8. Renal failure/AKI
9. Anastomotic leak

Bowel Resection/ Colectomy (based on 2010 MEDPAR data)

Complications are widespread

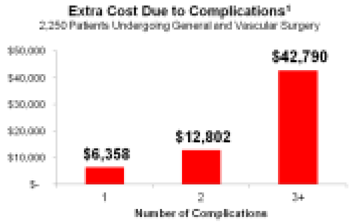
25%
post-surgical
complication rate[1]

Surgery	Morbidity rate[2]
Esophagectomy	55%
Pelvic exenteration	45%
Pancreatectomy	35%
Colectomy	29%
Gastrectomy	29%
Liver resection	27%

[1] Ghaferi, et al. *Variation in Hospital Mortality Associated with Inpatient Surgery.* N Engl J Med, 2009. (n=84,730)
[2] Schilling, et al. Prioritizing Quality Improvement in General Surgery. J Am Coll Surg. 2008. (n=129,233)

Complications are costly

$18,000
average extra cost for treating a patient developing one or more post-surgical complications, in US[1]

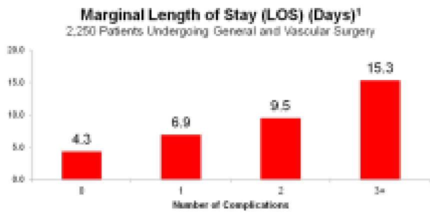


Added costs may include:

- Treatment (e.g., antibiotic, reintervention, anticoagulation)
- Lab tests
- Diagnostics
- Investigations
- Prolonged hospital length of stay
- Increased readmissions
- Decreased patient throughput

[1] Boltz, Melissa, et al. *Synergistic Implications of Multiple Postoperative Outcomes.* Am J Med Quality, 2012. (n=2,250, weighted average)

Complications extend LOS



Average **excess LOS** for adverse events = **9.8 days**
12,767 colectomies[2]

[1] Boltz, Melissa, et al. *Synergistic Implications of Multiple Postoperative Outcomes.* Am J Med Quality, 2012. (n=2,250)
[2] Schilling, et al. Prioritizing Quality Improvement in General Surgery. J Am Coll Surg. 2008. (n=12,767 colectomies)

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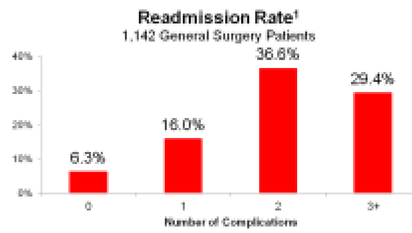
Complications lead to readmissions



- **Most significant independent risk factor for readmission**
- Any post-surgical complication increases the risk of readmission by a factor of four
  [odds ratio: 4.20; 95% CI: 2.89–6.13][1]
- **1 in 7 Medicare Pts are readmitted in 30 days[2]**

[1] Kassin, et al. *Risk Factors for 30-Day Hospital Readmission among General Surgery Patients*. J Am Coll Surg, 2012. (n=1,142 general surgery patients)
[2] Tsai, et al. NEJM, 2013.

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The pathogenesis of complications

Cardiac output 4-8 l/min

	Organ	***%***
	Brain	14
	Heart (Coronary Circulation)	3
	**Liver**	6
	Gastro-Intestinal System / Spleen	21
	Kidney	22
	Musculoskeletal	25
	Skin	6
	Bone, Other	8

Hori Qing mentioned (ed.), TEXT Physiology (3rd Edition), Nanshan Hall, 1999

Edwards

Helping Patients is Our Life's Work, and *life is now*