WORLD CONGRESS
ULTRASOUND IN MEDICAL EDUCATION

The Stethoscope of the Future
April 29–May 1, 2011
Columbia Metropolitan Convention Center
Columbia, South Carolina, USA

ECHO IN THE ICU

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WINFOCUS
World International Network Focused on Critical UltraSound

ECHOCARDIOGRAPHY IN THE ICU

1. **ICU** - THE SETTING
2. **ECHO** - PECULIAR FEATURES
3. **THE PHYSICIAN** - ECHO APPROACH TO HEMODYNAMICS
4. **EVIDENCE**

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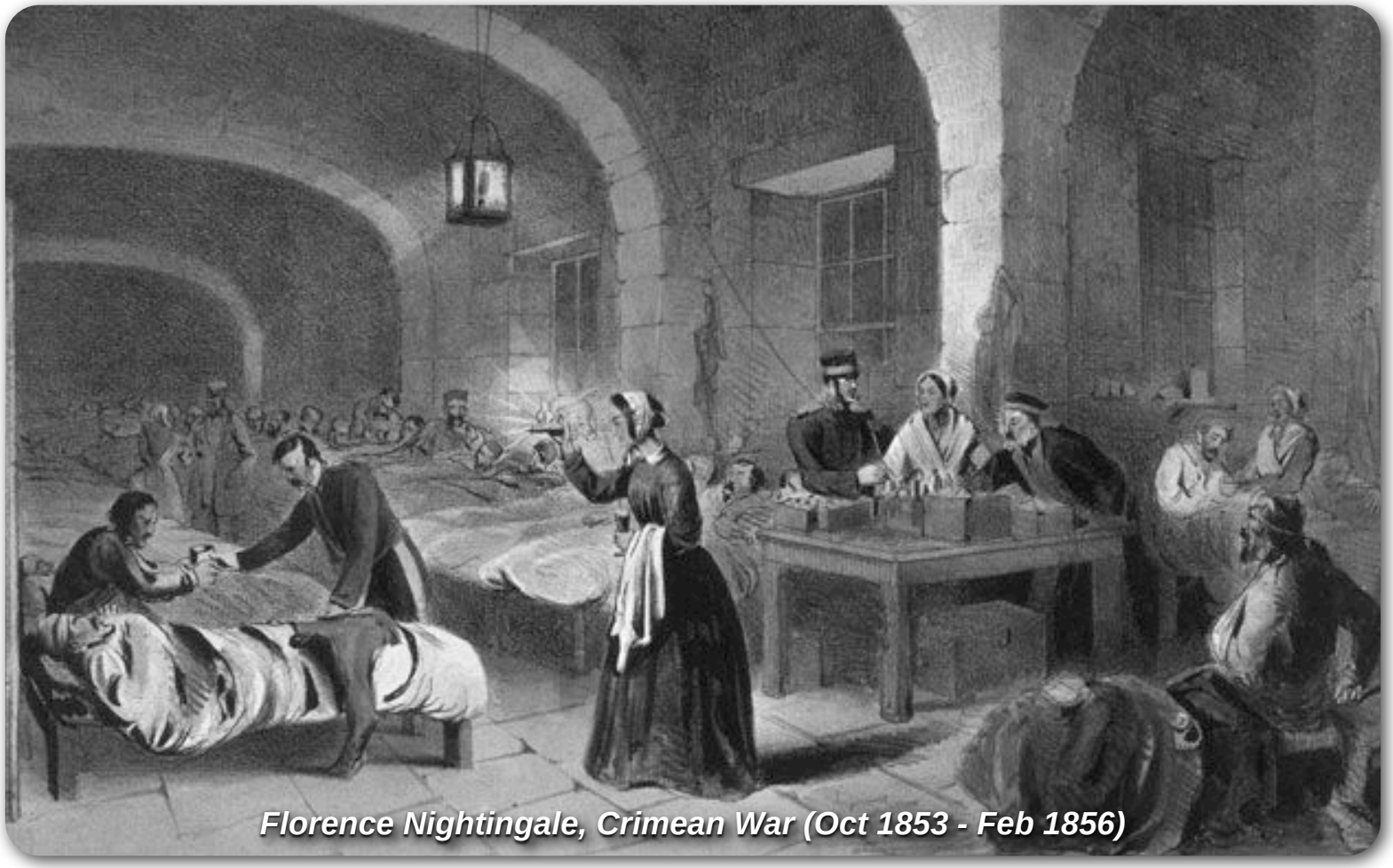
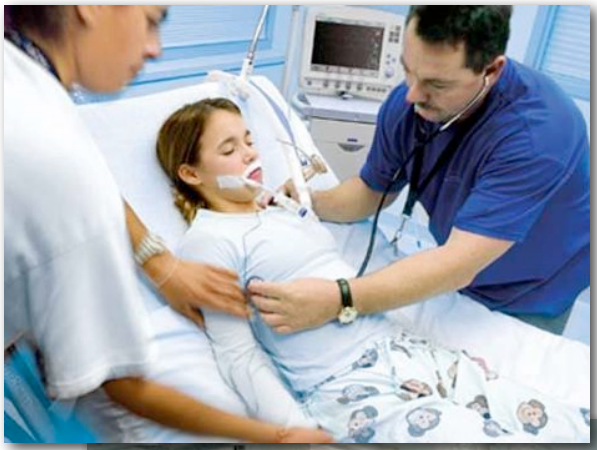
INTENSIVE CARE



Florence Nightingale, Crimean War (Oct 1853 - Feb 1856)

"The lady with the lamp"

INTENSIVE CARE UNIT



*"The combination in one **dedicated area of the hospital** of:*

- **TRAINED STAFF** - *holistic approach, looking to detect, evaluate, integrate and develop a set of priorieties and objective of care for the patient; multidisciplinary team; high nurse/patient & physician/patient ratio*
- **MONITORING & THERAPEUTIC DEVICES** - *full range, immediately availabile, scalable, tailored to patient needs"*

Moreno RP, Singer B, Rhodes A. What is an ICU? MWV, Berlin 2010

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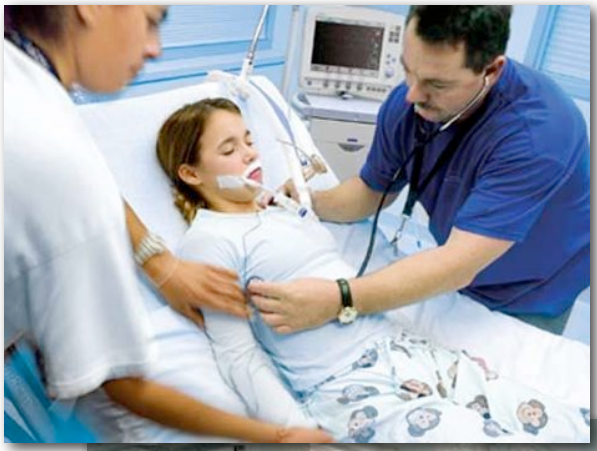
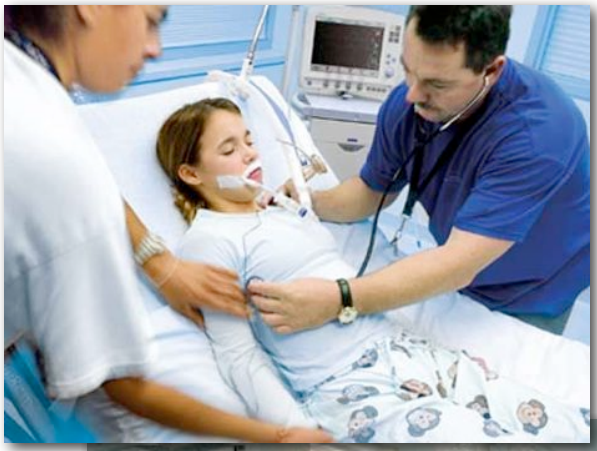
INTENSIVE CARE UNIT



COMPETENCE

EQUIPMENT

INTENSIVE CARE UNIT



COMPETENCE

EQUIPMENT

PRE-HOSPITAL/ED vs ICU

Disease Onset

First approach to patient

Frequently One-disease state

Potentially limited resources

Disease Evolution, Ongoing Treatment

“Second hand” patients

Complications, Overlapping diseases

Full-range Monitoring/Diagnostic capabilities

FOCUSED ECHO

(TTE, limited, 2-D, qualitative)

FOCUSED + Comprehensive

(TTE/TEE, exhaustive, 2-D/Doppler, quantitative)

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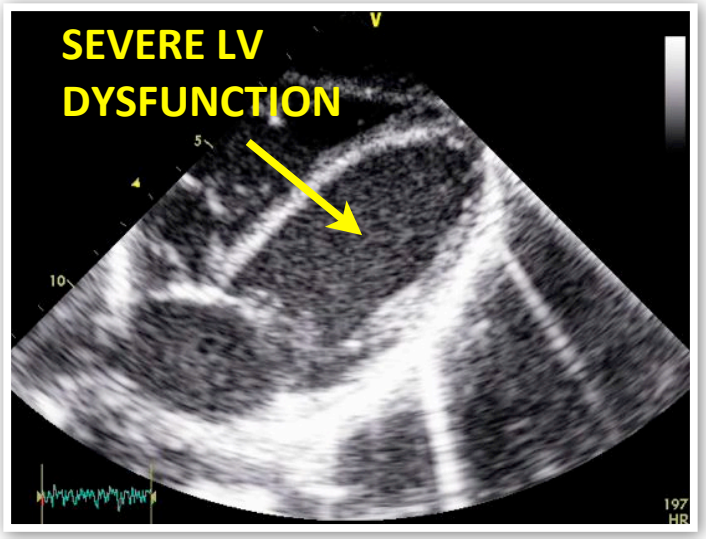
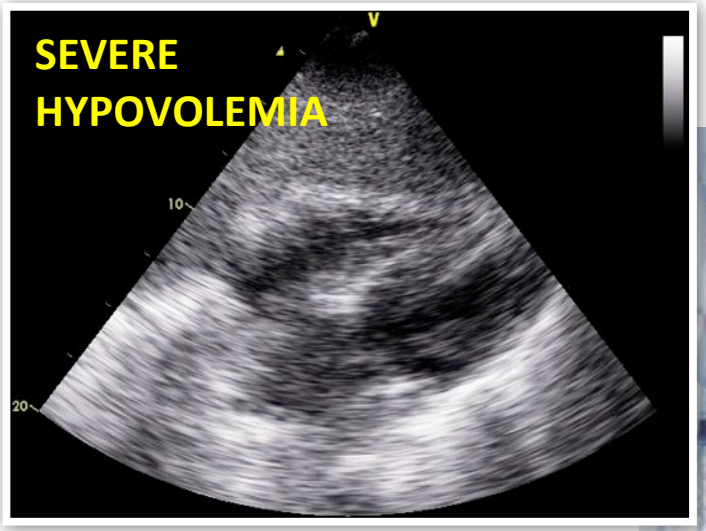
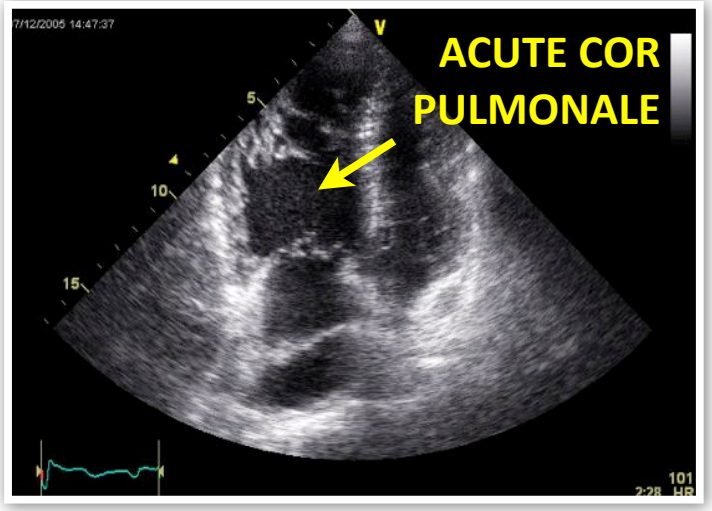
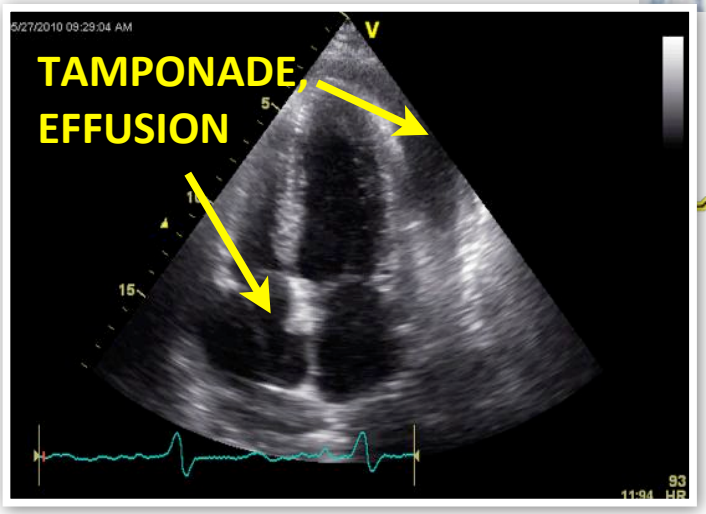
MET/RRT/CCOT

CARDIOVASCULAR FAILURE









MET Medical emergency team

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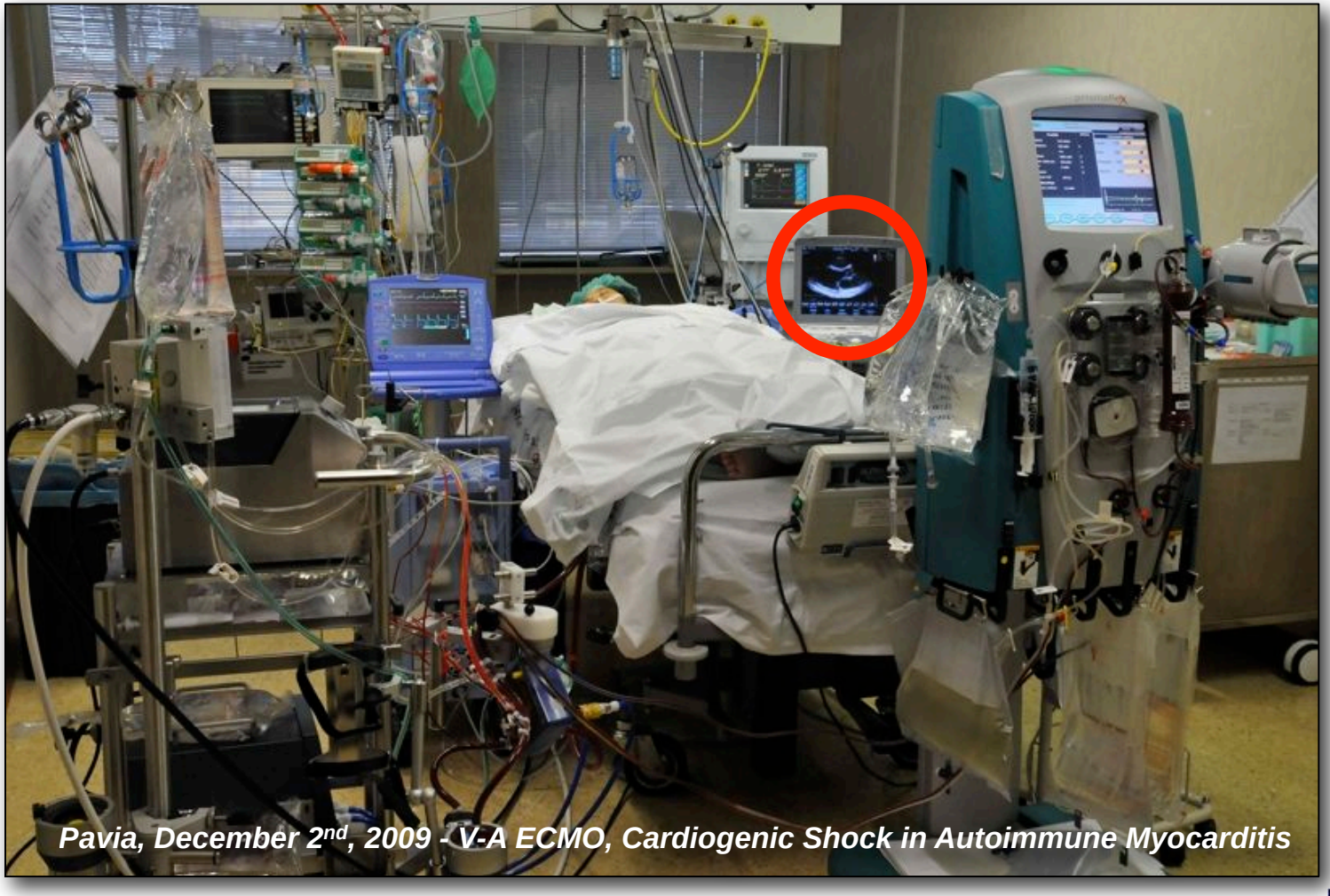
INTENSIVE CARE UNIT

CARDIOVASCULAR FAILURE



Pavia, December 2nd, 2009 - V-A ECMO, Cardiogenic Shock in Autoimmune Myocarditis

INTENSIVE CARE UNITS...

DEVELOPING COUNTRIES

INTENSIVE CARE UNITS...

REMOTE SETTINGS, BATTLE FIELDS, HUMANITARIAN MISSIONS

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INTENSIVE CARE UNITS...

MONITORING

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HEMODYNAMIC MONITORING in the ICU

MONITORING

"Continuous or intermittent observation of normal or altered physiological patient's parameters with an attitude to early detection of the need for therapeutic interventions"

(Bellomo R, CURR OPIN CRIT CARE 2003).

HEMODYNAMIC MONITORING in the ICU

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"Continuous or intermittent observation of normal or altered physiological patient's parameters with an attitude to early detection of the need for therapeutic interventions"

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THE IDEAL MONITORING TOOL

"Good monitoring should measure relevant variables, provide interpretable data, be easy to implement, and not cause harm. The ideal monitoring should be reliable, continuous, noninvasive, operator-independent and cost-effective, and should have a fast response time "

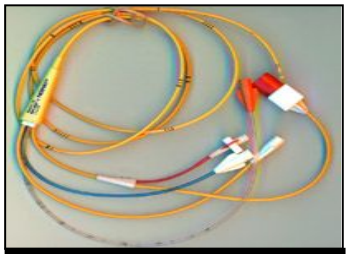
(Tobin M, post-graduate course on ICU monitoring. Congress of the ATS, San Diego, 2006).

Why Hemodynamics with an Imaging Technique (1) ?

NON-/ SEMI-INVASIVE, TIME-SAVING

Why Hemodynamics with an Imaging Technique (2)?

HEMODYNAMIC CATEGORIES vs AETIOLOGY



PAC

Low **CO**

Elevated **PAOP** & **CVP**

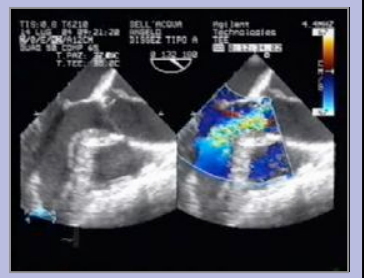
High **PAP**

High **SVR**

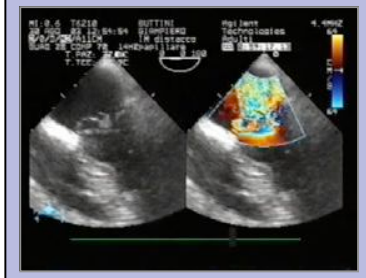
ECHO

AMI

Decompensated DCM



Acute AV Reguritation



Papillary Muscle Rupture

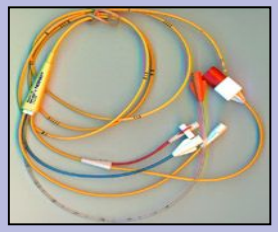
Localized LA Tamponade

MV Endocarditis

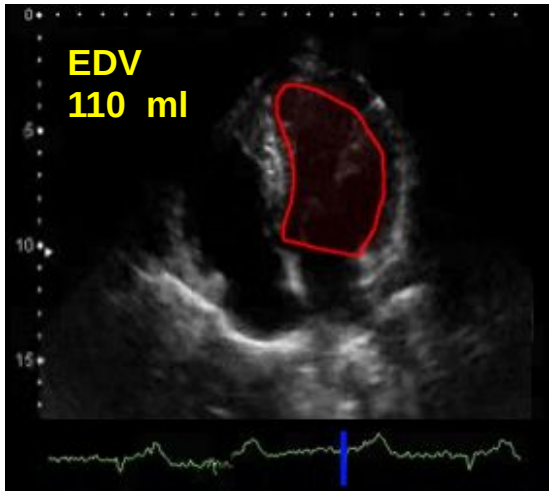
Why Hemodynamics with an Imaging Technique (3)?

CARDIAC "FUNCTIONAL RESERVE ESTIMATION"

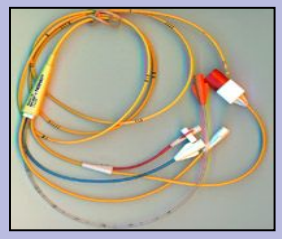
A



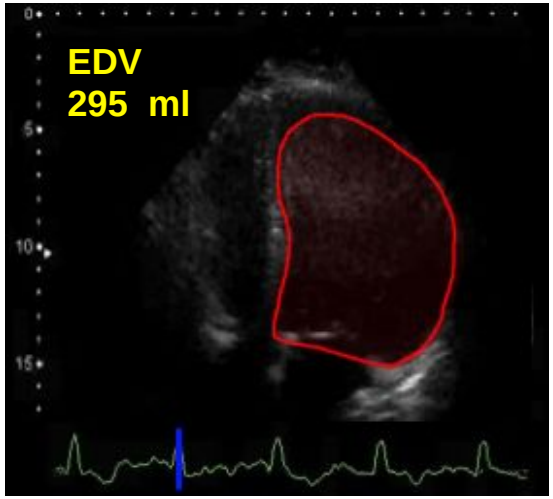
CO = 5,3 l/min
(71 ml x 75 bpm)



B

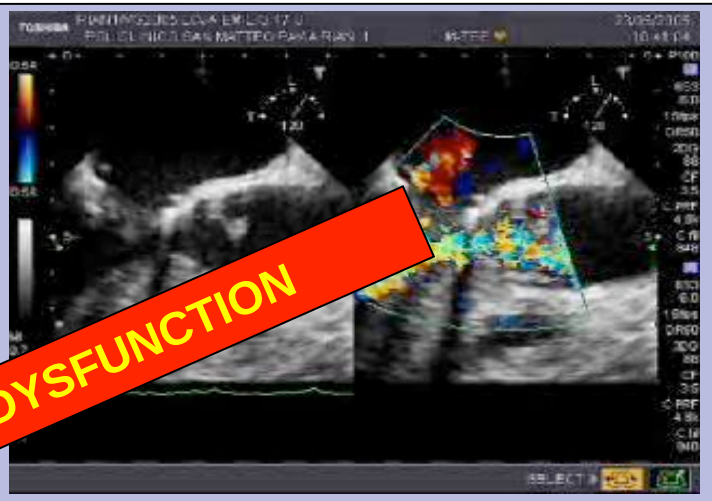


CO = 5,2 l/min
(73 ml x 72 bpm)



Why Hemodynamics with an Imaging Technique (4)?

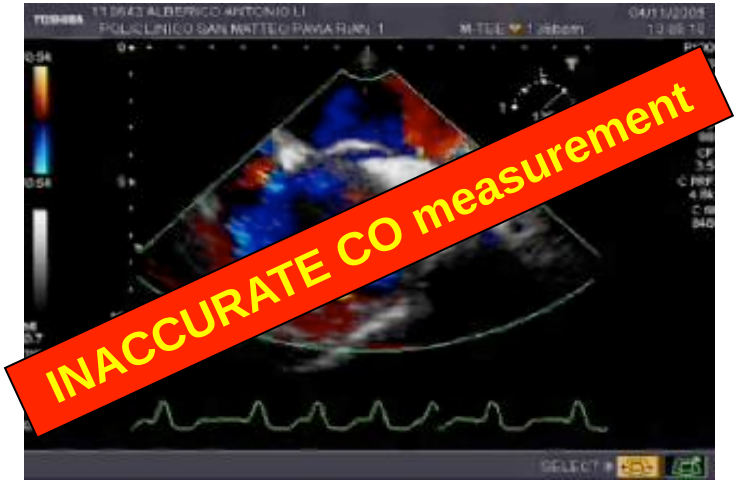
LV DIASTOLIC DYSFUNCTI



LVOT OBSTRUCTION, inotropes excess

HIGH PAOP, NO LV SYSTOLIC DYSFUNCTION

VENTRICULAR INTERDEPENDENCE



INACCURATE CO measurement

Severe IT, Intracardiac Shunts

Why Hemodynamics with an Imaging Technique (5)?

FLUID RESPONSIVENESS PARAMETER (CI increase > 15-20%)	Source	Pts N.	BEST THRESHOLD VALUE	POS Predictive Value (%)	NEG Predictive Value (%)
 CVP	Michard F, 2000	40	< 9 mmHg	50	50
	Barbier C, 2004	23	<7mmHg	67	57
	Schneider AJ, 1988; Wagner JG, 1998	18+17	None	-	-
 Wedge Pressure	Michard F, 2000	40	< 10 mmHg	41	44
	Tavernier B, 1998	35	< 10 mmHg	61	67
	Tousignant CP, 2000; Diebel L, 1992	21+29	None	-	-
Right Ventricular EDV (mod PAC)	Diebel L, 1994	32	< 90 ml/ m²	70	67
Δ CVP (spont breath)	Magder S, 1999	29	> 1 mmHg	77	81
Δ Down	Tavernier B, 1998	35	> 5 mmHg	95	93
Δ Pulse Pressure	Michard F, 2000	40	> 13%	94	96
Pass Leg Raising Δ	Monnet X, 2006	71	> 10%	94	97
 LV EDA	Tavernier B, 1998	35	< 9 cm/m²	67	70
	Feissel M, 2001	19	None	-	-
LVOT ΔV peak	Feissel M, 2001	19	> 12%	90	100
Δ Superior Vena Cava	Vieillard-Baron A, 2004	66	> 36%	100	91
Δ Inferior Vena Cava (Δ D_{IVC})	Feissel M, 2004	39	> 12 %	93	92
Δ Inferior Vena Cava (dIVC)	Barbier C, 2004	23	> 18%	90	90
Passive Leg Raising Δ CO	Maizel J, 2007	34	> 12%	100	75

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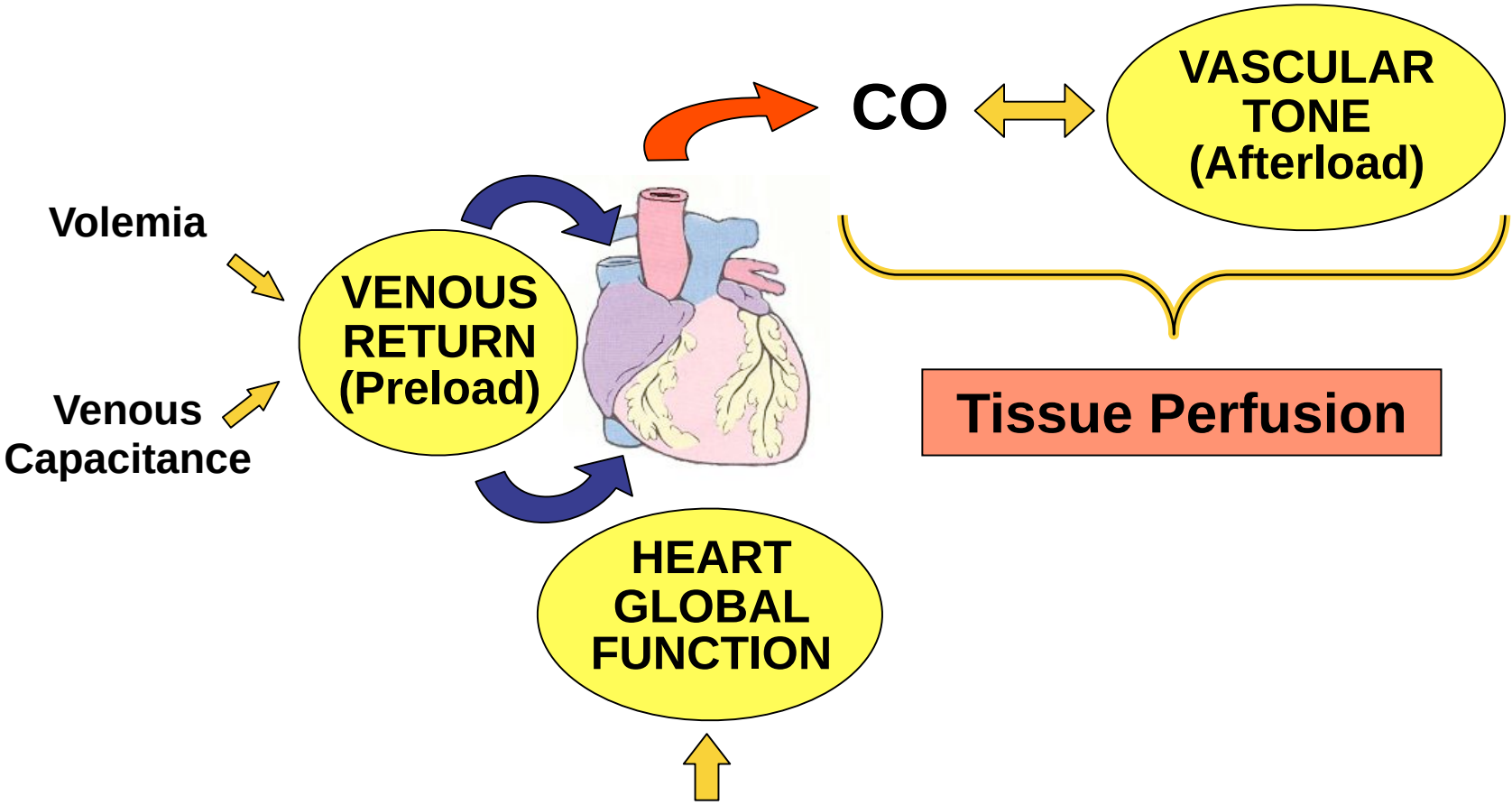
ECHO: A DEEP INSIGHT into CARDIOVASCULAR PATHOPHYSIOLOGY



ECHO HEMODYNAMIC VARIABLES

- *LV GLOBAL SYSTOLIC FUNCTION*
- *RV GLOBAL SYSTOLIC FUNCTION*
- *PAPs*
- *CO*
- *PRELOAD & PRELOAD RESPONSIVENESS*
- *LV FILLING PRESSURES*
- *VALVULAR DYSFUNCTION,*
  HEART STRUCTURAL ABNORMALITIES
- *LV DIASTOLIC DYSFUNCTION*
- *PERICARDIAL DISEASE*
- *AFTERLOAD*

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ECHO HEMODYNAMIC VARIABLES

- *LV GLOBAL SYSTOLIC FUNCTION*
- *RV GLOBAL SYSTOLIC FUNCTION*
- *PAPs*
- *CO*
- *PRELOAD & PRELOAD RESPONSIVENESS*
- *LV FILLING PRESSURES*
- *VALVULAR DYSFUNCTION, HEART STRUCTURAL ABNORMALITIES*
- *LV DIASTOLIC DYSFUNCTION*
- *PERICARDIAL DISEASE*
- *AFTERLOAD*

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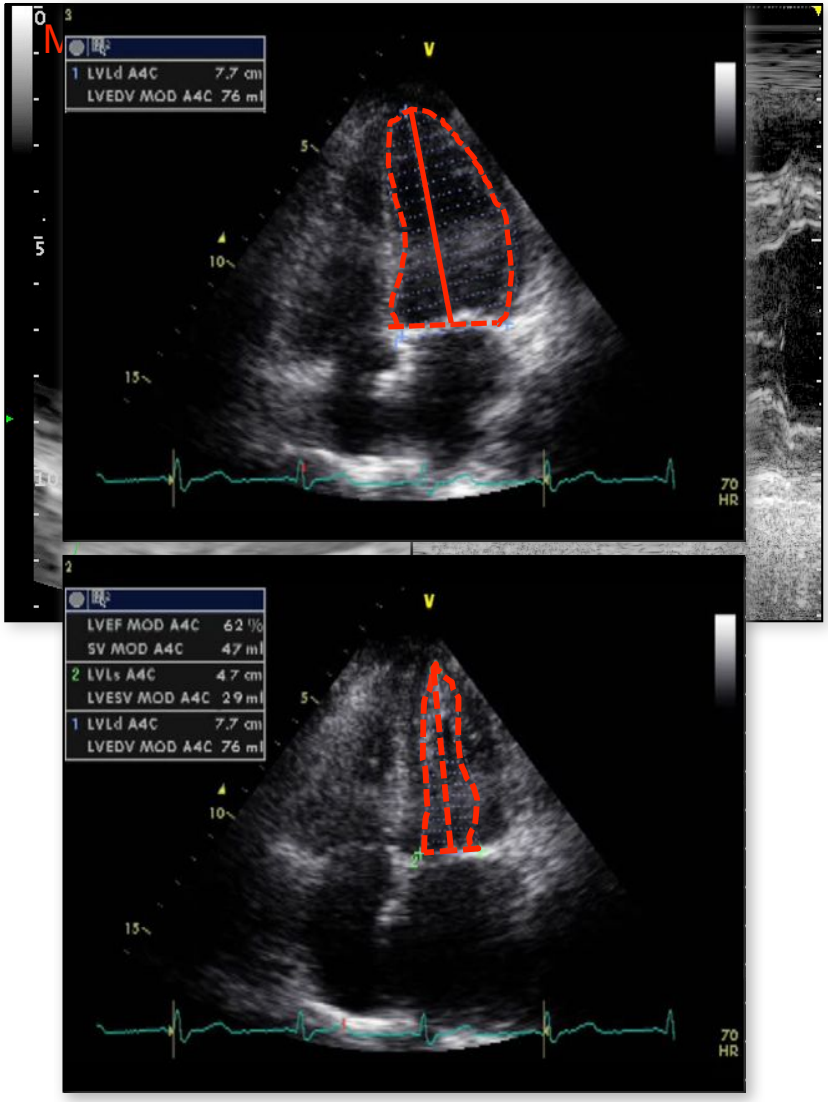
LV Global Systolic Function



Fra Ejection Fraction ıge

$$EF\ (\%) = 100\ x\ \frac{(\ LVEDV - LVESV\ )}{LVEDV}$$

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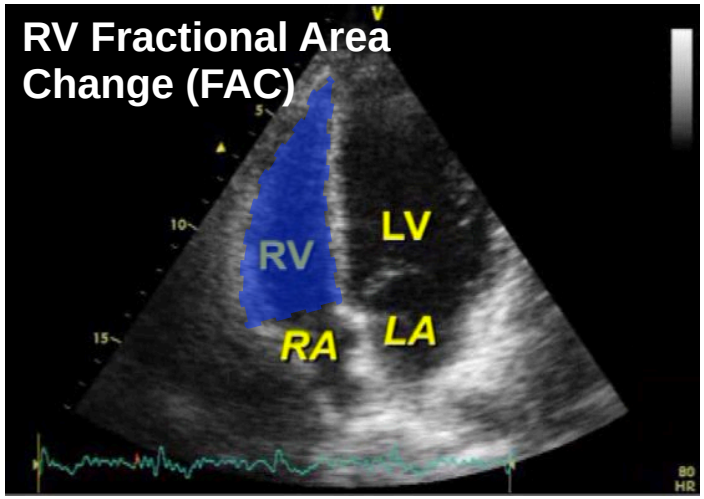
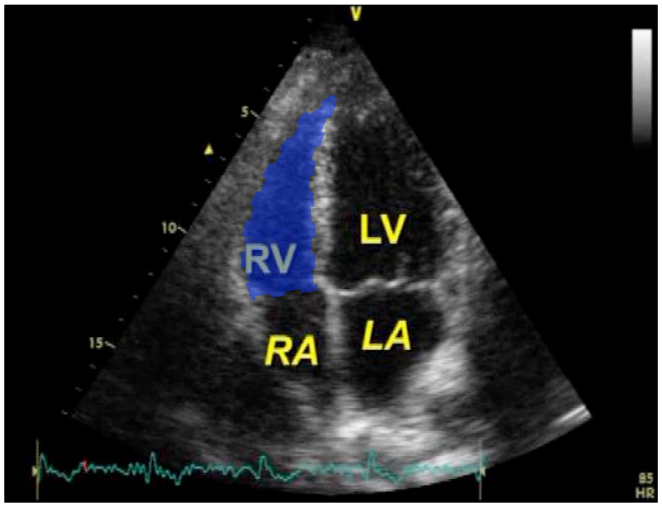
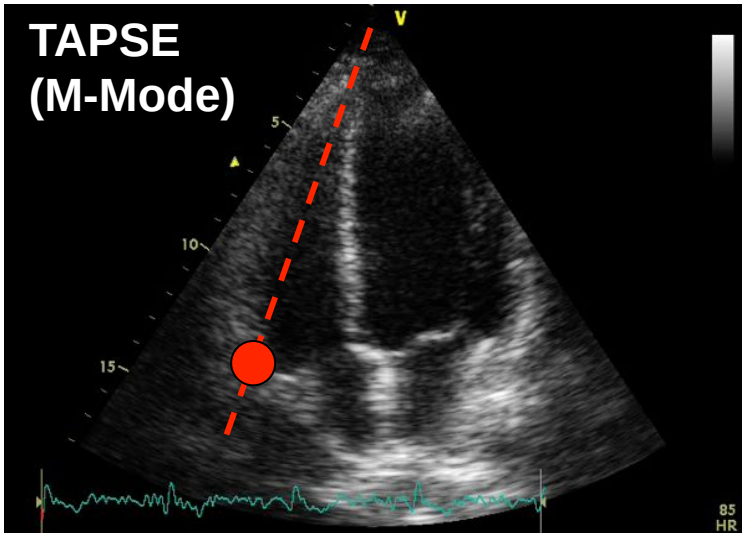
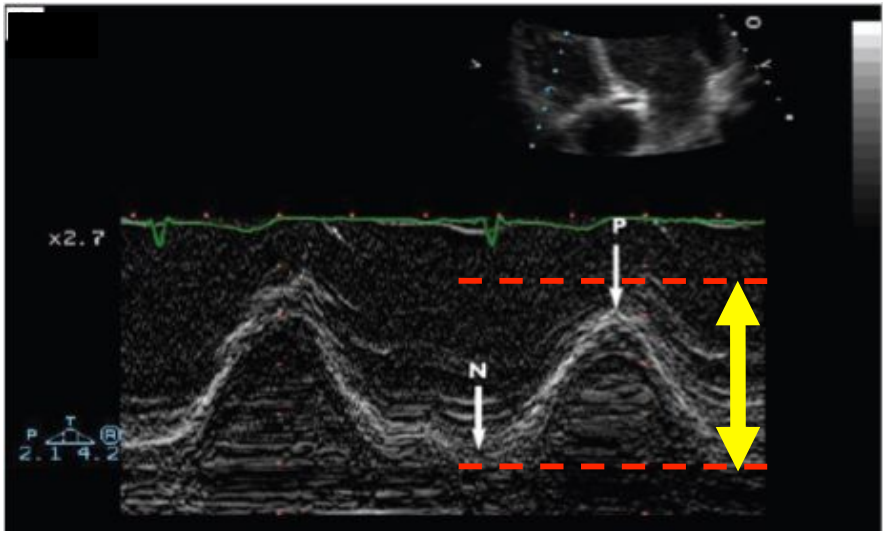
RV Global Systolic Function









Kaul S. Am Heart J 1984

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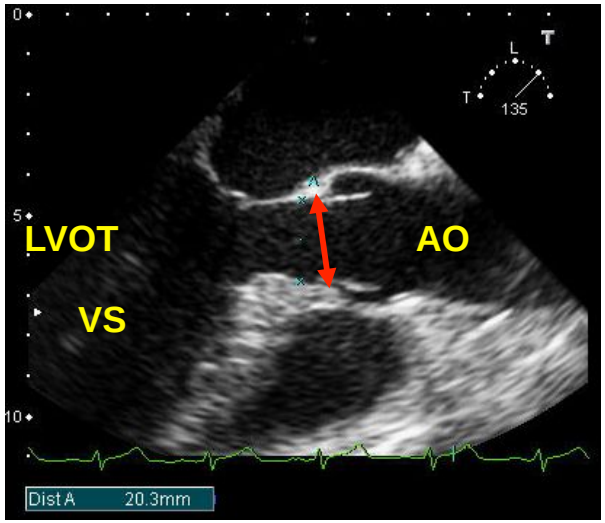
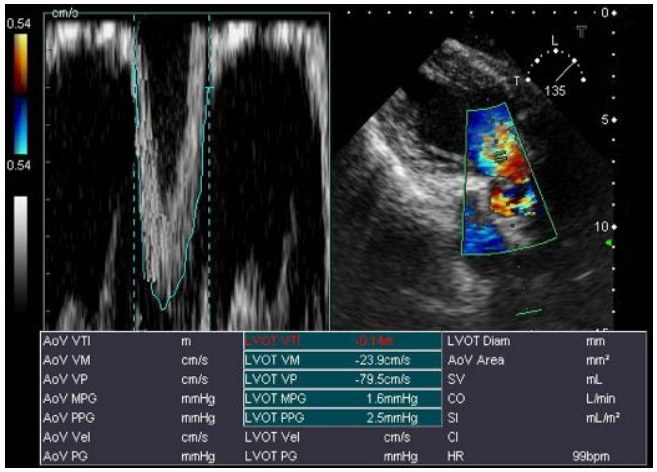
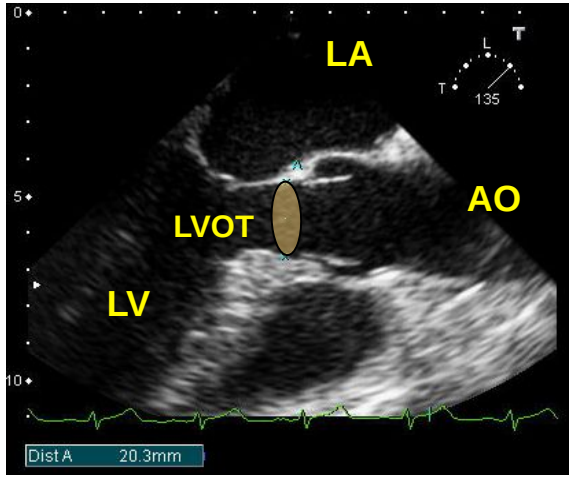
Stroke Volume (CO) estimation





X



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STROKE VOLUME

LVOT VTI

LVOT Cross Sectional Area

Feinberg MS. CHEST 1995

Darmon PL. ANESTHESIOLOGY 1994

Descorps-Declere A. INT CARE MED 1996

Stroke Volume (CO) estimation

Thermodilution CO – Echo Doppler CO Agreement				
	setting	N	r	Bias (±2SD)
Darmon (1994)	Intraoperative	63	0.94	0.06 ± 0.83 l/min
Feinberg (1995)	Intraoperative, Cardiological ICU	29	0.91	0.1 ± 0.70 l/min
Descorps-Declere (1996)	ICU	28	0.97	- 0.42 ± 1.3 l/min
Perrino (1998)	Intraoperative	32	0.91	0.01 ± 1.12 l/min
Royse (1999)	Intraoperative	37	0.92	0.01 ± 1.10 l/min
Zhao (2003)	Intraoperative	30	0.87	0.07 ± 0.86 l/min
Bettex (2004)	Intraoperative	30	0.89	0.36 ± 0.50 l/min

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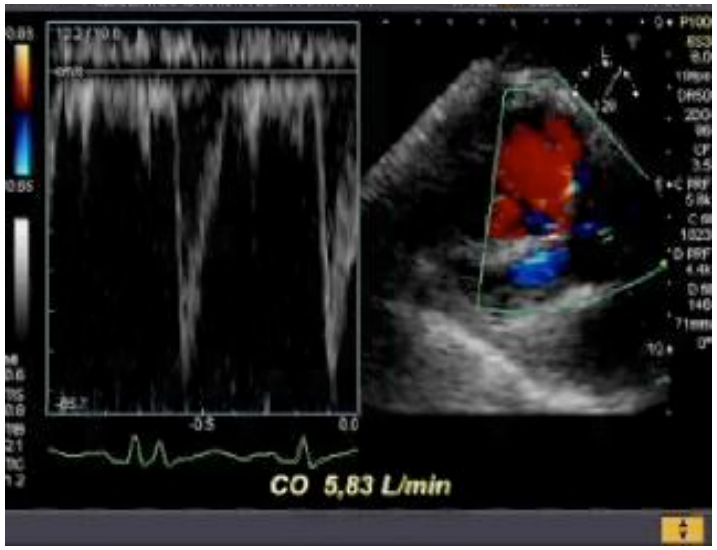
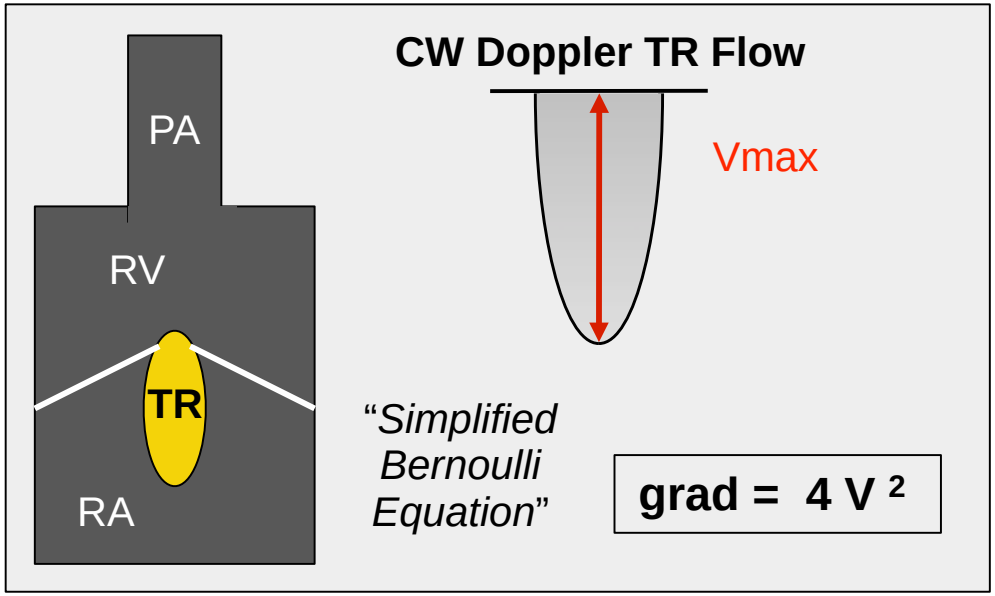
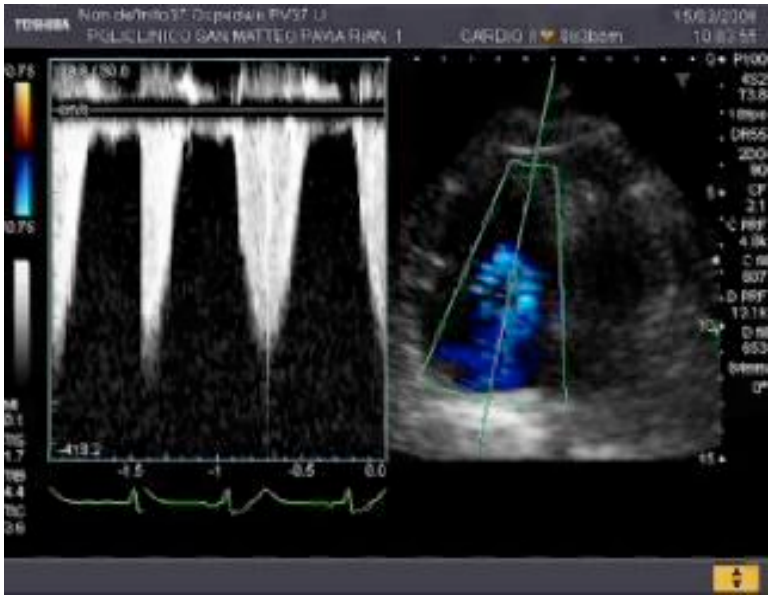
Stroke Volume (CO) estimation

Epinephrine
0.1 mcg/Kg/min



PAP Measurement

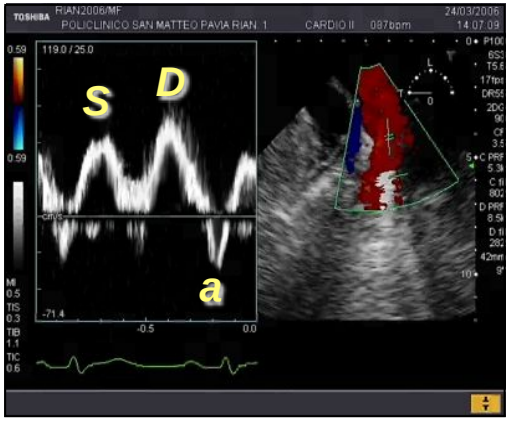


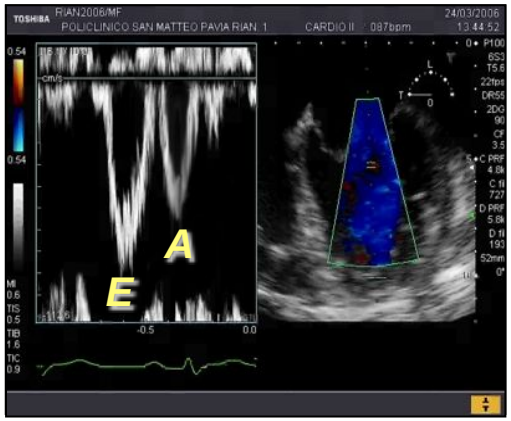


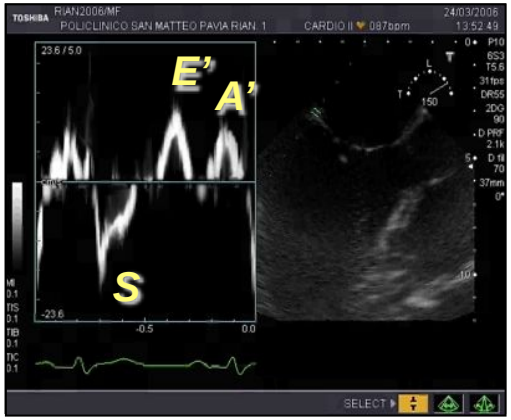
PAPs = grad RV - RA + CVP

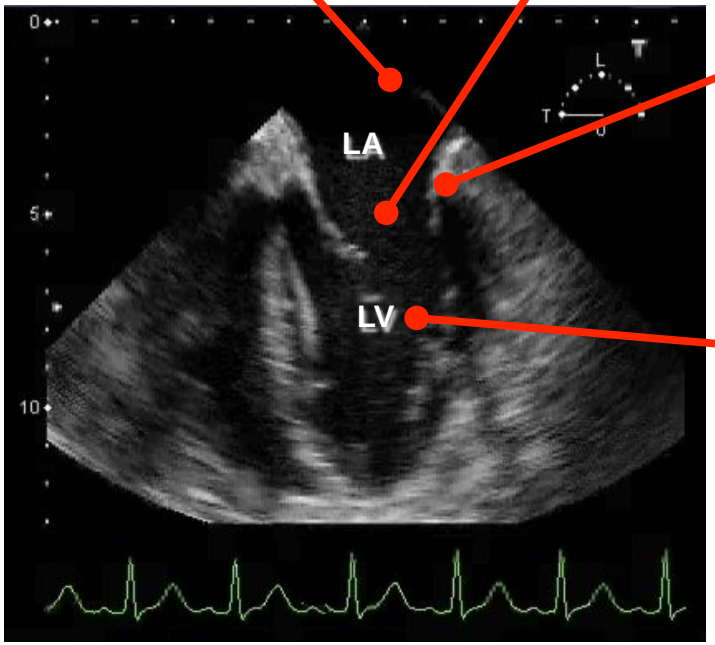
PAPs = 4 V max ² + CVP

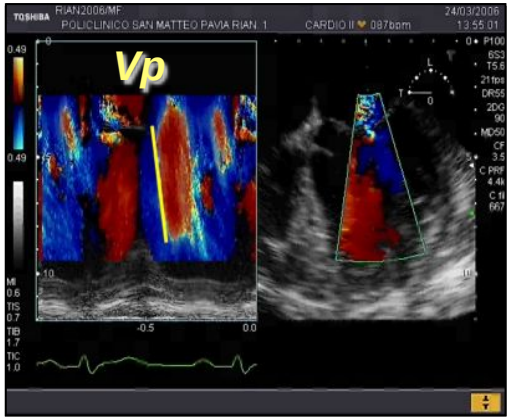
LV Filling Pressures estimation











LEFT ATRIAL PRESSURE

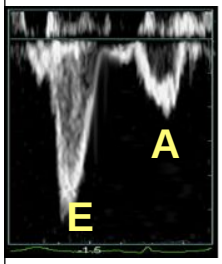
Low

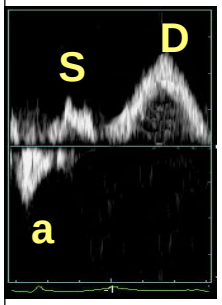
Normal

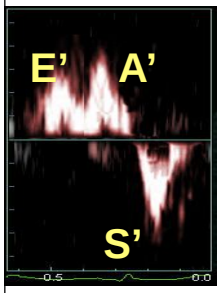
High

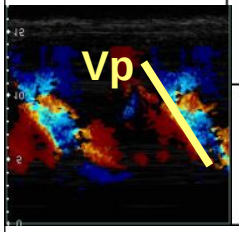
Very High

LV Filling Pressures estimation





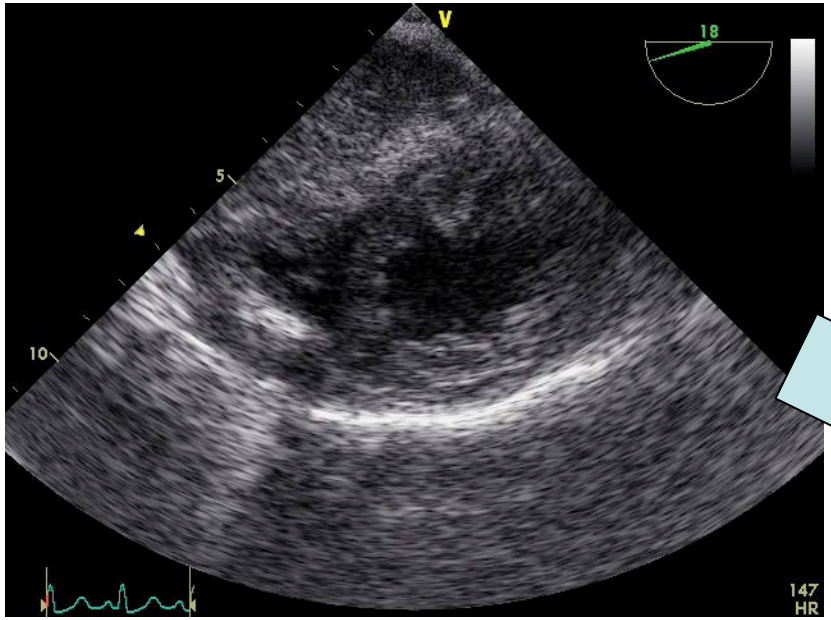




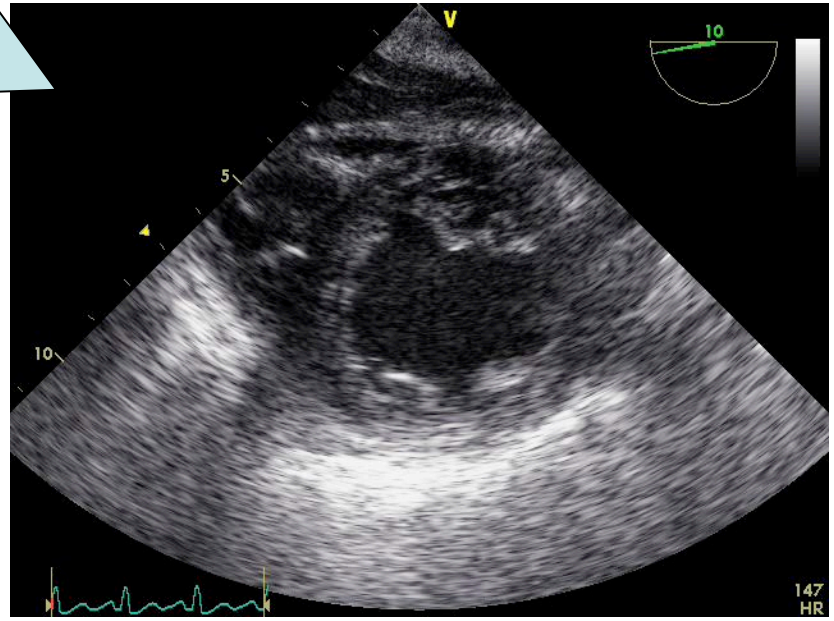
Doppler parameters	Threashold values	Predicted PAOP	Sensitivity	Specificity	Positive predictive value
E/A	> 2	> 18 mmHg	-	-	100%
Systolic fraction	< 55%	> 15 mmHg	91%	87%	-
	< 40%	> 18 mmHg	-	-	55%
	= 40%	= 18 mmHg	100%	100%	100%
	= 44%	> 18 mmHg	85%	88%	-
TD_D	< 175 ms	= 18 mmHg	100%	94%	-
E/E'	> 15	> 15 mmHg	86%	88%	-
	> 7	= 13 mmHg	86%	92%	-
	> 7,5	= 15 mmHg	86%	81%	-
	> 9,5	> 18 mmHg	100%	86%	-
E/Vp	> 2	= 13 mmHg	-	-	-
	> 2,6	> 18 mmHg	100%	86%	-

Adapted from: Vignon P. RÉANIMATION 2007

Volume Responsiveness Indices (1): LVEDA



Crystalloids 1,5 L



End Systolic LV obliteration ("Kissing Walls")

LV EDA < 5,5 cm/m^2 *Body Surface Area*

Cheung AT. ANESTHESIOLOGY 1994 - Feissel M. CHEST 2001 - Leung JM, ANESTHESIOLOGY 1994

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Volume Responsiveness Indices (2): H-L Interactions

FLUID RESPONSIVE

NON RESPONSIVE

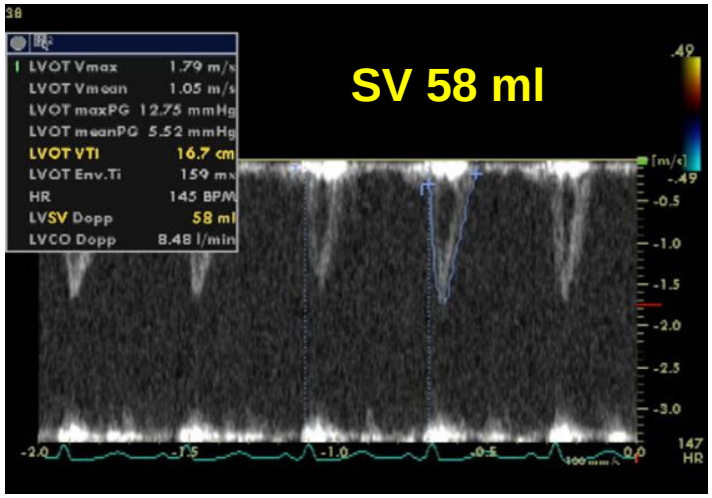
Feissel M. CHEST 2001 - Vieillard-Baron A. INTENSIVE CARE MED 2004 - Barbier C. INTENSIVE CARE MED 2004

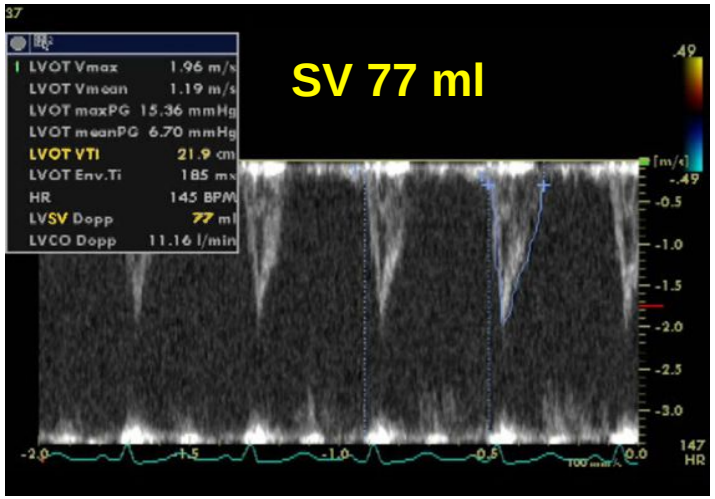
Volume Responsiveness Indices (3): PASSIVE LEG RAISING (PLR)

BASAL

ΔSV PLR > 12%

PLR

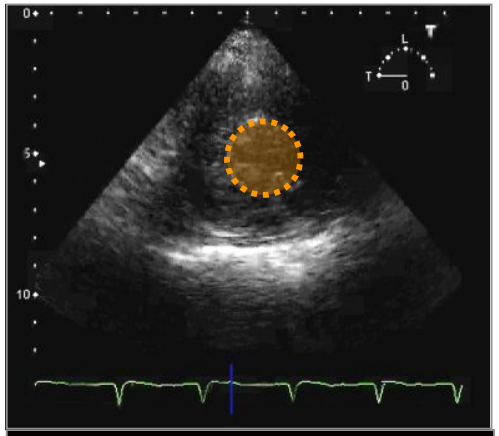




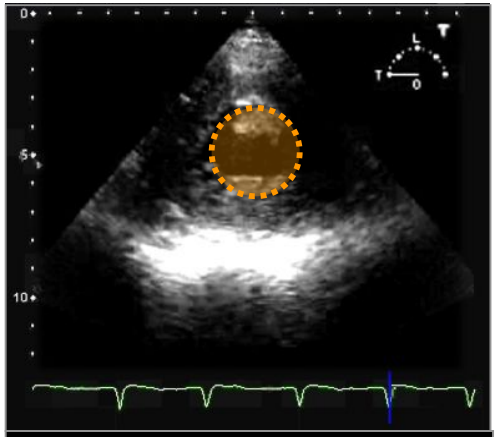
Lamia B. INT CARE MED 2007 – Meizel J. INT CARE MED 2007

Afterload (1)

HYPOVOLEMIA

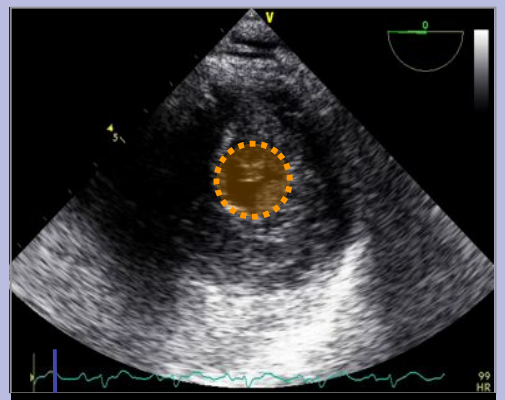


Low ESA

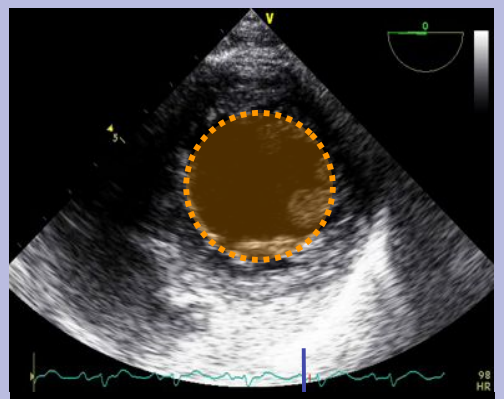


Low EDA

VASODILATATION



Low ESA



Normal EDA

Afterload (2)

“ Exclusion Criteria”

Hypotension

RV DILATION - SYSTOLIC DYSFUNCTION ?

NO

LV SYSTOLIC DYSFUNCTION? DIASTOLIC DYSFUNCTION? VALVULAR DYSFUNCTION?

NO

LOW PRELOAD , PRELOAD RESPONSIVENESS?

NO

Vasodilation !

Hemodynamic Technique: "ECHODINAMICS "

1st TEE ASSESSMENT

2nd TEE ASSESSMENT

3rd TEE ASSESSMENT

TEE in place

Colloids 1500 ml

Nor 0.9 mcg/Kg/min

Cristalloids 1500 ml

Norepinephrine 0.9 mcg/Kg/min

Colloids 500 ml

t

SEPTIC SHOCK

HEMODYNAMIC INSTABILITY

SAP 80/40, CVP 11,
SpO2 98%, SVcO2 58%,
Oliguria, Lactacidemia

SAP 110/40, CVP 13,
SVcO2 65%, Diuresis
50 ml/h, Lactacidemia

SAP 135/50, CVP 14,
SVcO2 73%, Diuresis
120 ml/h, No Lactates

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ECHOCARDIOGRAPHY IN THE ICU

1. ICU - THE SETTING
2. ECHO - PECULIAR FEATURES
3. THE PHYSICIAN - ECHO APPROACH TO HEMODYNAMICS
4. **EVIDENCE**

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ECHO IN ICU: EVIDENCE

"In God we trust.

All others must bring data"

W. Dewards Deming
(1900-1993)

physicist and quality improvement pioneer

ECHO in ICU: GUIDELINES?

Table 2 Cardiovascular Evaluation in an Acute Setting

	Indication	Appropriateness Score (1–9)
	Hypotension or Hemodynamic Instability	
11.	Evaluation of hypotension or hemodynamic instability of uncertain or suspected cardiac etiology	A (9)
	Myocardial Ischemia/Infarction	
12.	Evaluation of acute chest pain with suspected myocardial ischemia in patients with nondiagnostic laboratory markers and ECG and in whom a resting echocardiogram can be performed during pain	A (8)
13.	Evaluation of suspected complication of myocardial ischemia/infarction, including but not limited to acute MR, hypoxemia, abnormal chest X-ray, VSD, free-wall rupture/tamponade, shock, right ventricular involvement, heart failure, or thrombus	A (9)
	Respiratory Failure	
14.	Evaluation of respiratory failure with suspected cardiac etiology	A (8)
	Pulmonary Embolism	
15.	Initial evaluation of patient with suspected pulmonary embolism in order to establish diagnosis	I (3)
16.	Evaluation of patient with known or suspected acute pulmonary embolism to guide therapy (i.e., thrombectomy and thrombolytics)	A (8)

ACC/ASE/ACEP/ASNC/SCAI/SCCT/SCMR 2007
Appropriateness Criteria for Transthoracic and Transesophageal Echocardiography

A Report of the ACC Foundation Quality Strategic Directions Committee Appropriateness Criteria Working Group, ASE, ACEP, ASNC, SCAI, SCCT, and the SCMR. *Endorsed by the ACCP and the SCCM*

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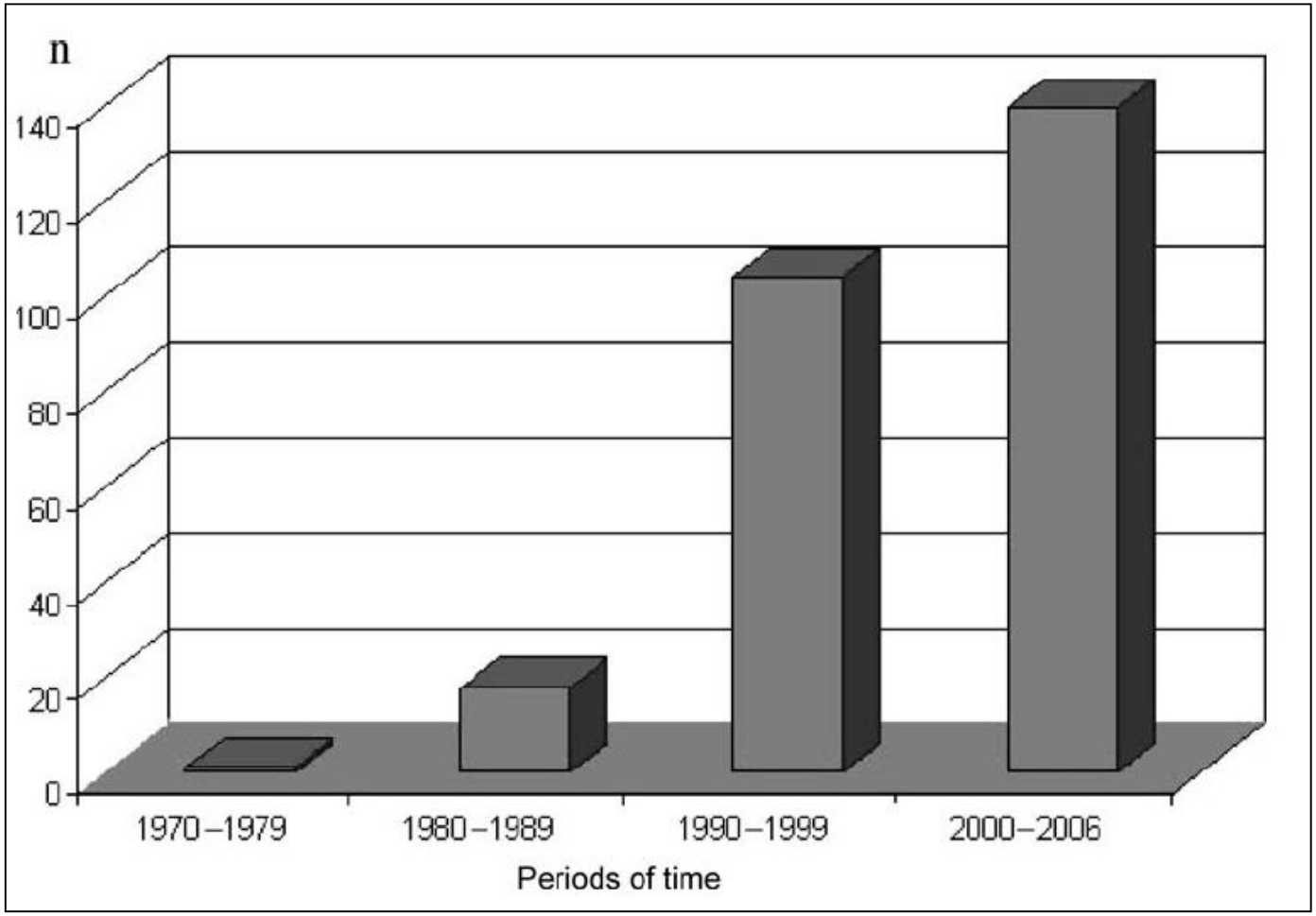
ECHO in ICU: GROWING INTEREST

Search in PubMed for published manuscripts in peer-reviewed journals related to the use of echocardiography in ICU settings during four consecutive periods.

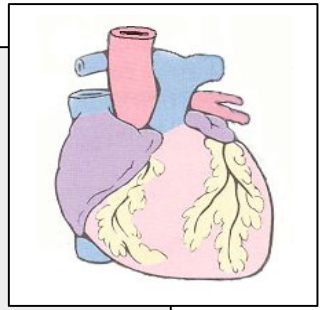


Vieillard-Baron A. INTENSIVE CARE MED 2008

ECHO in ICU: GROWING SUPPORT

- ICU echocardiography - should we use it in a heartbeat? *Chest 2002*
- Portable echocardiography - is essential for the management of acutely ill patients. *BMJ 2006*
- Overview of Transesophageal Echocardiography for the Chest Physician. *Chest 2003*
- Echocardiography for the intensivist. *Care of the Critically ill 2003*
- Bedside Ultrasonography in the ICU. *Chest 2005*
- Echo in ICU – time for widespread use! *Intensive Care Medicine 2006*

PREVALENCE of CARDIAC PATHOLOGY in ICU



ICU Prevalence of Occult Cardiac Abnormalities

TTE, N = 500, over 12 months period

Overall:	35% (169 pts) 1 or more
Unsuspected in:	77.0% (130 on 169 pts)

No increased Mortality in Cardiac Abnormality pts

Increased ICU and Hospital length of Stay

Bossone E. *Range and Prevalence of Cardiac Abnormalities in Patients Hospitalized in a Medical ICU.* CHEST 2002.

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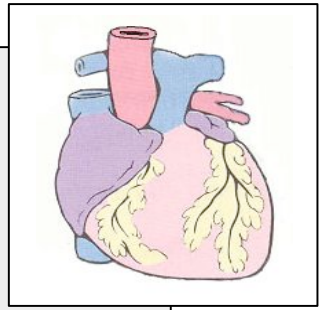
PREVALENCE of CARDIAC PATHOLOGY in ICU



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ECHO THERAPEUTICAL IMPACT: ICU vs Others

Prospective, structured Interview

Assessment of diagnostic and therapeutic implications of ECHO perceived by physicians and subsequently confirmed by blinded chart review

TTE, N = 542, over 5 months period

Treatement Changes, ICU vs Non ICU pts: 54% vs 37%

Tam J. *What is the Real Clinical Utility of Echocardiography? A Prospective Observational Study.* JASE 1999.

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ECHO IMPACT in ICU

TEE IMPACT IN ICU 20 studies, N = 2508

weighted means: 67.2% diagnostic

36.0% medical therapeutic

14.1% surgical therapeutic

Huettemann E. *The Use and Safety of TEE in the general ICU: a mini-Review.* ACTA ANAESTH SCAND 2004.

48.5% NEW DIAGNOSIS with TEE in PAC pts

Harris KM. *ECHOCARDIOGRAPHY 1999*.

44% THERAPY CHANGES after TEE in PAC pts

Polaert JI. *CHEST 1995*.

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ECHO IMPACT in ICU

Prospective audit of all echocardiograms, (TTE & TEE) performed in a general ICU

N = 258 (TTE 72.4%, TEE 27.6 %), over 2 years

"Management was changed directly as a result of information provided in 51.2% of studies. Changes included fluid administration, inotrope or other drug therapy, and treatment limitation"

Orme RM. *Impact of echocardiography on patient management in the intensive care unit: an audit of district general hospital practice.* BJA 2009

ECHO vs. other Monitoring Tools

	ECHO	PAC	PiCCO
Based on	**Images/Flows** (ultrasound)	**Pressures, Flows** (thermodilution)	**Pressures, Flows** (transpulmonary thermodilution)
Type of monitoring	**Intermittent**	**Continuous**	**Continuous**
Monitoring onset	**Rapid**	**More delayed**	**More delayed**
Invasiveness	**None** (TTE), minimal (TEE)	**Yes** (catheter into PA)	**Yes** (modified CVC, large bore peripheral artery)
CO/CI measurement	Less accurate (more reliable in detecting changes)	Clinical gold standard	Accurate
Systolic function	Clinical gold standard, separate assessment of LV and RV	Global pump function (CO, SV), RVEF*	Global pump function (GEF)
Preload	**Measured Volumes/Dimensions** (LVEDA, LVEDV, IVC D)	**Pressures** (PAOP, CVP) Calculated Volumes (CEDV*)	**Calculated Volumes** (GEDV)
Preload responsiveness	**Accurate in MV-SR patients** (ΔVpeak, ΔVTI, ΔSVC, ΔIVC). **High specificity, lower sensitivity in SR/NSR patients** (PLR induced LVOT VTI increase)	**Limited** (top/bottom of values range of PAOP, CVP). **ΔPP in MV/SR patients accurate. Inaccurate in SV/NSR patients** (only fair correlation with PLR induced PP increase)	**Accurate** (ΔPP, ΔSV) in MV/SR patients. **Inaccurate in SV/NSR patients** (no data yet on PLR induced SV increase)
Diastolic function	**Clinical Gold Standard**	**No**	**No**
Systemic vascular resistances	**Just clues**	**Calculated from CO, MAP and CVP**	**Calculated from CO, MAP and CVP**
Adequacy of perfusion	**No§**	**SVO2**	**SVcO2**
Valves, Pericardium, Structural abnormalities	**Gold Standard**	**No**	**No**
Training	**Longer**	**Short**	**Short**
Reproducibility of measurements	**Operator dependent**	**Less operator dependent**	**Less operator dependent**

HEMODYNAMIC MONITORING in the ICU

MONITORING

"Continuous or intermittent observation of normal or altered physiological patient's parameters with an attitude to early detection of the need for therapeutic interventions"

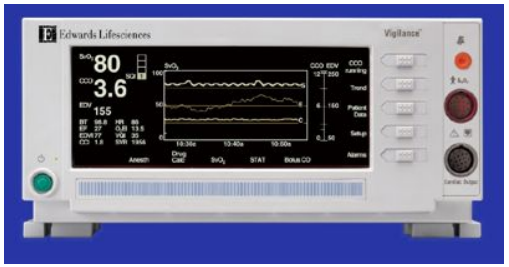
(Bellomo R. CURR OPIN CRIT CARE 2003).

THE IDEAL MONITORING TOOL

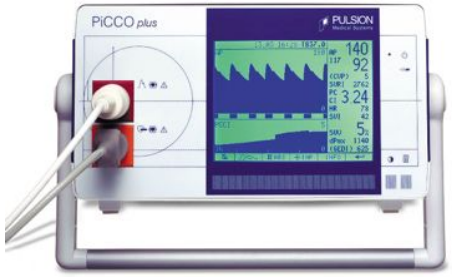
"Good monitoring should measure relevant variables, provide interpretable data, be easy to implement, and not cause harm. The ideal monitoring should be reliable, continuous, noninvasive, operator-independent and cost-effective, and should have a fast response time "

(Tobin M, post-graduate course on ICU monitoring. Congress of the ATS, San Diego, 2006).

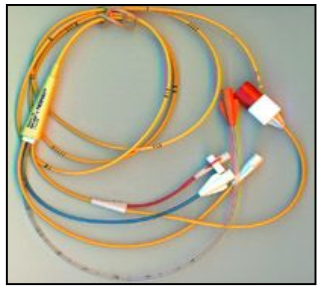
An “Echocentric” view of Hemodynamics



Advanced PAC



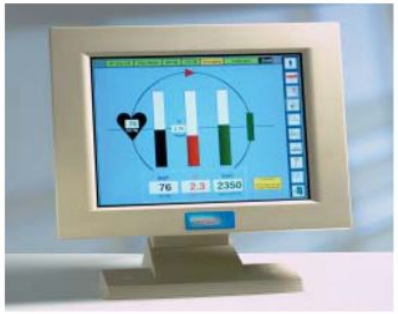
PiCCO*plus* ®



PAC

MOSTCARE®

Vigileo®



LiDCO®

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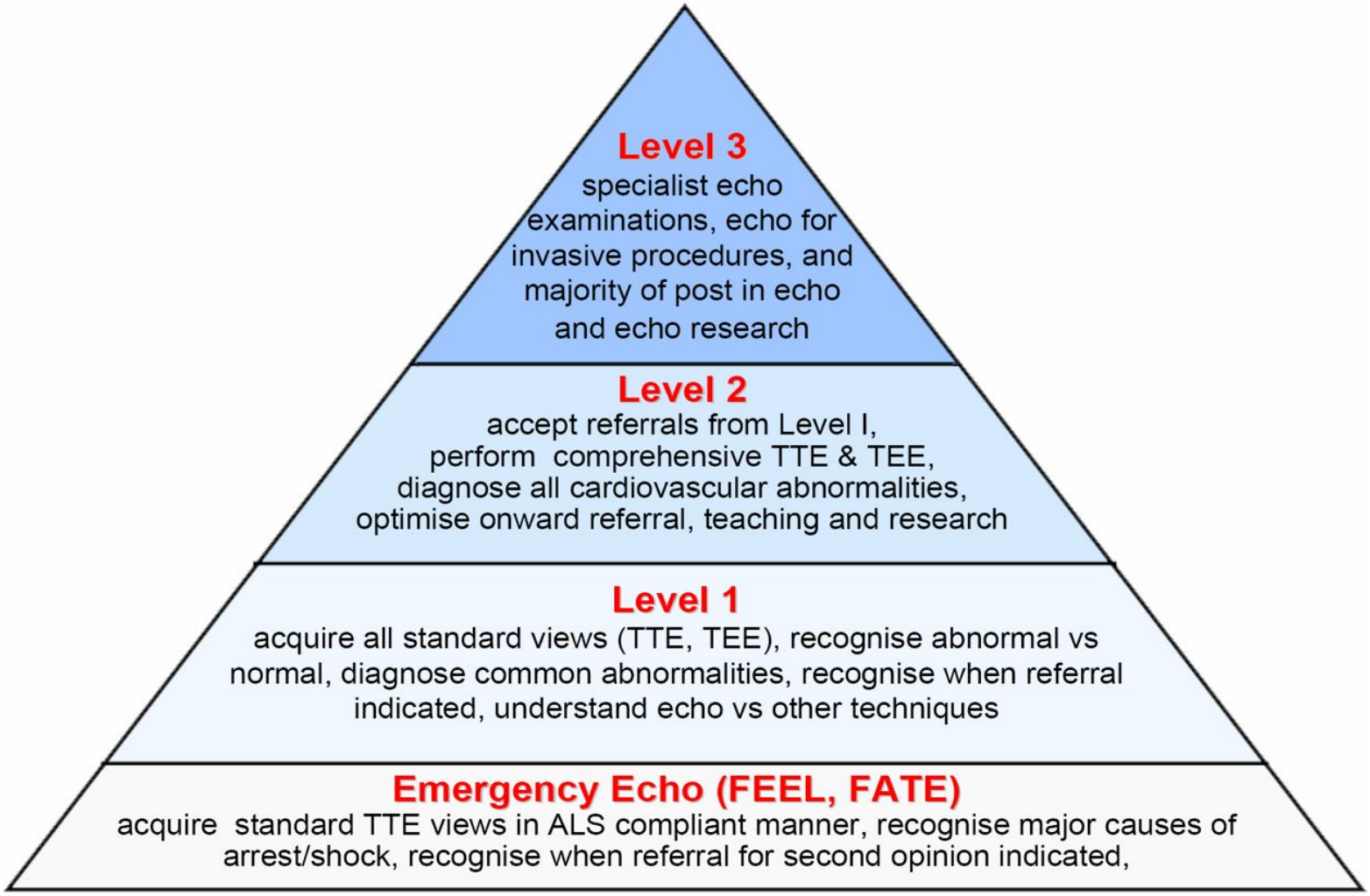
4 Good reasons NOT to use Echo - Monitoring

1. Need for Continuous CO monitoring
2. Need for Continuous PAP monitoring
3. Need for precise PAOP or SVR measurment
4. INABILITY TO USE IT

   (lack of training)

ECHO COMPETENCE in ICU



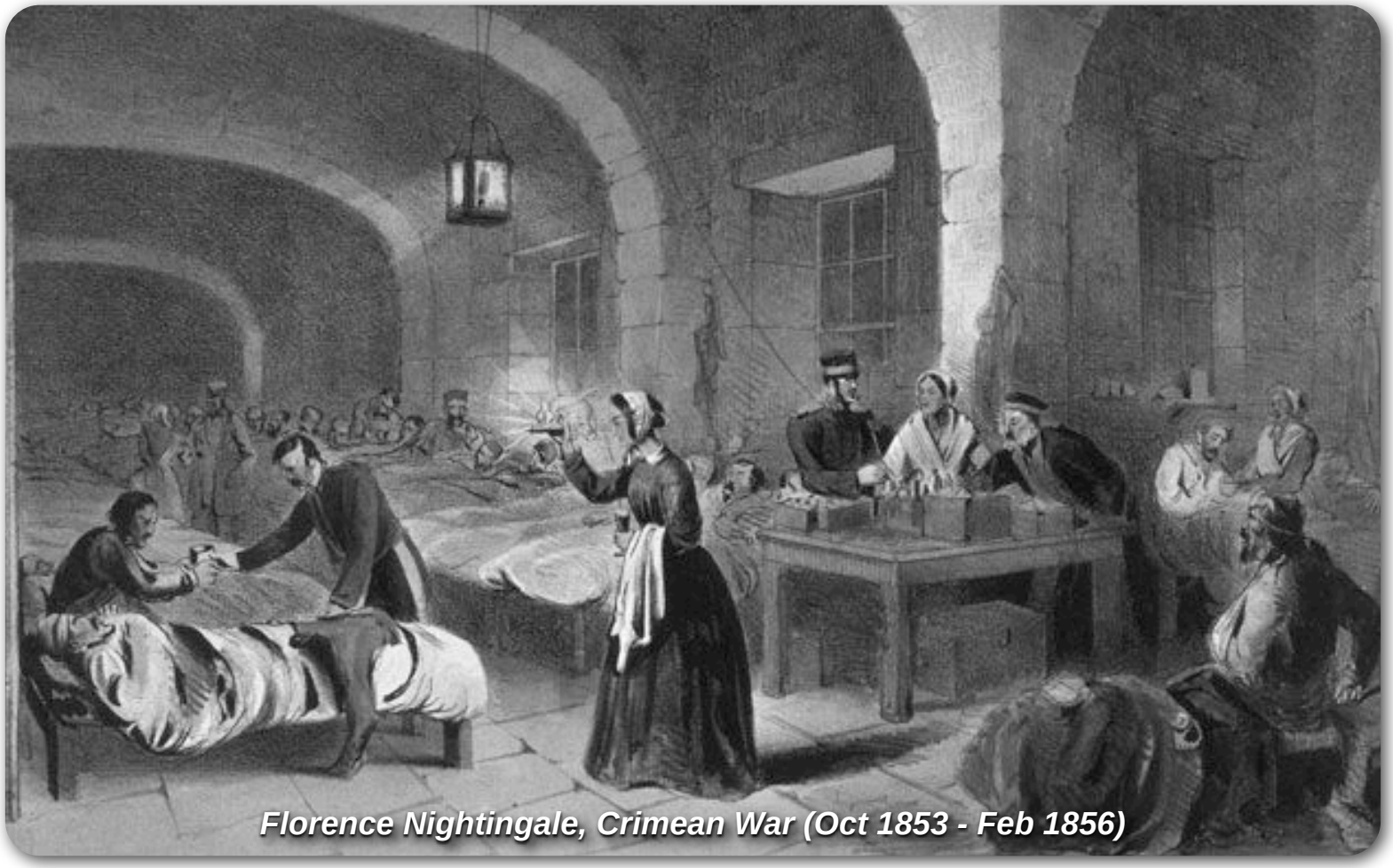
Price S, Via G, Sloth E, et al. Echocardiography Practice, Training and Accreditation in the Intensive Care: document for the World Interactive Network Focused on Critical UltraSound (WINFOCUS). CARDIOVASC ULTRASOUND 2008

TAKE HOME MESSAGES

ECHO IN THE ICU

- May be more complex than prehosp/ED
- Can fully dysplay its monitoring/diagnostic capabilities
- With other monitoring tools / In isolation (scarce resources)
- Hemodynamic Approach
- May require longer training than Focused
- Should be done!

INTENSIVE CARE



Florence Nightingale, Crimean War (Oct 1853 - Feb 1856)

"The lady with the lamp"

INTENSIVE CARE

"The men (& women) with a probe"

WORLD CONGRESS
ULTRASOUND IN MEDICAL EDUCATION

The Stethoscope of the Future
April 29–May 1, 2011
Columbia Metropolitan Convention Center
Columbia, South Carolina, USA

ECHO IN THE ICU

Gabriele Via, M.D.

1st Department of Anesthesia and Intensive Care
Fondazione IRCCS Policlinico San Matteo - Pavia
Università degli studi di Pavia, Italy

WINFOCUS
World International Network Focused on Critical UltraSound