ショックの4分類

閉塞性

緊張性気胸　Lung sliding

心タンポナーデ　心嚢液

肺塞栓　右室拡大・DVT

心原性

CO＝1回拍出量×HR

筋の異常　収縮能の目測

弁の異常　粗大病変の確認

脈の異常　ECG・モニタ

Hypovolemic shock & Distributive shock

血管内volume loss（絶対的 or 相対的）
Volume challenge＋原因への介入

BROWN
Alpert Medical School

Care New England

POCUSによる血行動態の評価

ブラウン大学医学部　内科　南太郎

Director, Medical Simulation and POCUS Training
Department of Medicine, Care New England

Associate Professor of Medicine, Clinician Educator
Associate Professor of Medical Science, Clinician Educator
The Warren Alpert Medical School of Brown University

京都大学医学部　臨床教授
東京女子医科大学　客員教授

1

COI開示: FUJIFILM, JICAのコンサルタント ケニアでのPOCUS指導

I am a consultant of FUJIFILM Corp, Japan in association to the project funded by Japan International Cooperation Agency (JICA) concerning the "SDGs Business Verification Survey with the Private Sector for Point of Care Ultrasound through Professional Capacity Development in Kenya"

2020年2月　ケニア、ナイロビ

2

POCUSによる血行動態の評価

POCUSの定義
(1)Acquisition
(2)Interpretation
(3)Immediate clinical integration

of ultrasonographic imaging performed by a treating clinician at the patient's bedside

Diaz-Gomez, Mayo, Koenig, Point-of-Care Ultrasonography, N Engl J Med 2021; 385:1593-1602

3

POCUSによる血行動態の評価

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4

POCUSによる血行動態の評価 プロトコールは世に沢山あります

Table 3: Summary of the major ultrasound protocols for medical shock assessment.

Protocol	ACES [4]	BEAT [5]	BLEEP [6]	Boyd: ECHO [7]	EGLS [8]	Elmer/ Noble [9]	FALLS [10]	FATE [13]	FEEL: RESUS [14]	FEER [15]	FREE [16]	POCUS [17]	RUSH: HIMAP [18]	RUSH: Pump Tank Pipes [19, 20]	Trinity [21]	UHP [22]
Cardiac	1	1	1	1	2	1	3	1	1	1	1	3	1	1	1	3
IVC	2	2	2	2	3	2	4					4	2	2		
FAST A/P	4					3						1	3	3	3	1
Aorta	3											5	4	7	2	2
Lungs PTX					1	4	2					2	5	6		
Lungs effusion	5							2						4		
Lungs edema					4	5	1					6		5		
DVT												7		8		
Ectopic Pregnancy												8				

Numbers indicate exam sequence for each protocol.

Seif D, Perera P, Mailhot T, Riley D, Mandavia D. Bedside Ultrasound in Resuscitation and the Rapid Ultrasound in Shock Protocol. Critical Care Research and Practice. 2012;2012:503254.

5

POCUSによる血行動態の評価 プロトコールは世に沢山あります

RUSH: Rapid Ultrasound for Shock and Hypotension (Emergency Medicine)

FALLS: Fluid Administration Limited by Lung Sonography (Lichtenstein)

FEEL: Focused Echocardiographic Evaluation in Life support (Breitkreutz)

FEER: Focused Echocardiographic Evaluation in Resuscitation Management (Breitkreutz)

FATE: Focus-Assessed Transthoracic Echocardiography

→沢山ありすぎて分からない？

→ でも基本を押さえれば迷うことはないでしょう

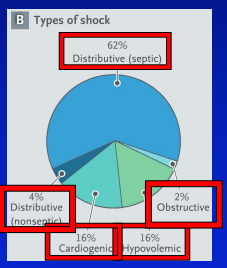
6

原則その1
ショックの原因には4つある

循環血液量減少性 (Hypovolemic)
心原性 (Cardiogenic)
閉塞性 (Obstructive)
血液分布異常性 (Distributive)

7

原則その2: Think about probability



Distributive (sepsis) 62%
Hypovolemic 16%
Cardiogenic 16%
Distributive (nonseptic) 4%
Obstructive 2%

Vincent JL, De Backer D. Circulatory shock. N Engl J Med. 2013 Oct 31;369(18):1726-34

8

原則その3　画像を組み合わせる

	循環血漿量減少性	心原性	閉塞性	血液分布異常性
IVC	Collapsed	Distended	Distended	Normal/ Collapsed
心臓エコー	**LV**: Hyperdynamic End-systolic effacement **RV**: normal or small size	**LV**: severely reduced, dilated chamber **RV**: possible dilated chambe Valves: MR/AR, AS	**LV**: Tamponade (hyperdynam pericardial effusion, RV diastolic collapse, RA systolic collapse) **RV**: (PE) Dilated, Strained,	**LV**: Hyperdynamic or normal (early) Hypocontractile(late) **RV**: normal or small size
肺エコー	A-line predominant (-) pleural effusion	B-line predominant (+) Pleural effusion	Pneumothorax (No sliding lung, A-line predominant) (+/-) Pleural effusion	Pneumonia B-line or C-profile PLAPS
腹部・血管エコー	**Abdomen**: aneurysm, dissection Intra-abdominal fluid **Vascular:** Collapsed veins	**Abdomen**: Peritoneal fluid in chronic LV/RV failure	**Vascular**: LE DVT	**Abdomen**: possible peritoneal fluids (peritonitis)

Modified from Lacticova V, Narasimahn M, Hypotension and Shock in Soni N, Arntfield R, Kory P ed. Point-of-Care Ultrasound 2015

9

ご静聴誠に有り難うございました

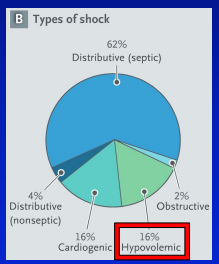
南太郎
Taro Minami, MD

ご質問あればお気軽に！
E-mail:
nantaro@gmail.com
taro_minami@brown.edu

Robert Thom, Laennec and the Stethoscope, courtesy of University of Michigan Museum of Art

10

Hypovolemic Shock



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Vincent JL, De Backer D. Circulatory shock. N Engl J Med. 2013 Oct 31;369(18):1726-34

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循環血液量減少性 (Hypovolemic)

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心臓エコー	**LV**: Hyperdynamic End-systolic effacement **RV**: normal or small size	**LV**: severely reduced, dilated chamber **RV**: possible dilated chamber Valves: MR/AR, AS	**LV**: Tamponade (hyperdynamic, pericardial effusion, RV diastolic collapse, RA systolic collapse) **RV**: (PE) Dilated, Strained,	**LV**: Hyperdynamic or normal (early) Hypocontractile(late) **RV**: normal or small size
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Modified from Lacticova V, Narasimahn M, Hypotension and Shock in Soni N, Arntfield R, Kory P ed. Point-of-Care Ultrasound 2015

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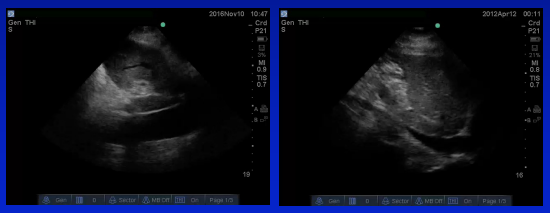
IVCによる Hypovolemiaと輸液反応性の評価



13

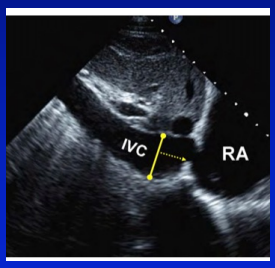
IVCと右房圧：ASE

Inferior Vena Cava	呼吸 or “Sniff”での変化	推定右房圧 (mmHg)
正常 (<2.1 cm)	減少 >50%	0-5 (3)
中等度		5-10 (8)
拡大 (>2.1cm)	減少 < 50%	10-20 (15)

J Am Soc Echocardiogr 2010;23:685-713

14

どこを計測するか: ASE



肝静脈流入部の足側で IVC壁から垂直に計測する (JASE 2010)

流入部から1–2 cmで計測する (JASE 2015)

J Am Soc Echocardiogr 2010;23:685-713

15

IVCとHypovolemia 何故混乱するのか？

(1) IVCで何を見てるの？輸液反応性？右房圧？
(2) 患者さんは挿管されている？自発呼吸？
(3) どのIndexを使っている?
→ (Dmax – Dmin) / Dmax
→ (Dmax – Dmin) / Dmean

16

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J Am Soc Echocardiogr 2010;23:685-713

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輸液反応性あり: 定義

輸液反応性あり: 輸液後 Cardiac Output が10% 以上増加

Cardiac Outputの計測: 1回拍出量 x 心拍数
1回拍出量の計測: Cross Sectional Area (CSA) x Velocity Time Integral (VTI)

Airapetian et al. Critical Care (2015) 19:400

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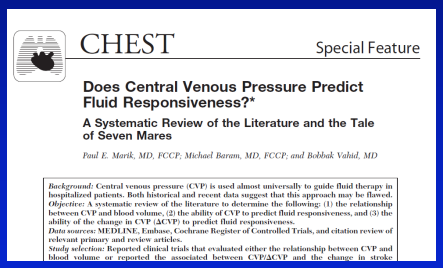
右房圧(CVP)と輸液反応性
Systematic Review



CHEST Special Feature

Does Central Venous Pressure Predict Fluid Responsiveness?*

A Systematic Review of the Literature and the Tale of Seven Mares

Paul E. Marik, MD, FCCP; Michael Baram, MD, FCCP; and Bobbak Vahid, MD

Background: Central venous pressure (CVP) is used almost universally to guide fluid therapy in hospitalized patients. Both historical and recent data suggest that this approach may be flawed. *Objective:* A systematic review of the literature to determine the following: (1) the relationship between CVP and blood volume, (2) the ability of CVP to predict fluid responsiveness, and (3) the ability of the change in CVP (ΔCVP) to predict fluid responsiveness. *Data sources:* MEDLINE, Embase, Cochrane Register of Controlled Trials, and citation review of relevant primary and review articles. *Study selection:* Reported clinical trials that evaluated either the relationship between CVP and blood volume or reported the associated between CVP/ΔCVP and the change in stroke

Marik P CHEST 2008; 134:172–178

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Systematic Review
CVPと輸液反応性

AUC of the ROC
- 0.56

Pooled correlation coefficient
- 0.18

20

右房圧 ≠ 輸液反応性

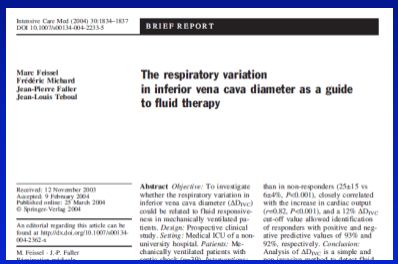
右房圧は輸液反応性の予測には使えないかも

21

混乱の背景 (2):
そのエビデンス、自発呼吸の患者さんについて？
それとも挿管患者さんに対するエビデンス？

22

IVCの変化率と輸液反応性
挿管されている患者さんでのエビデンス



Intensive Care Med (2004) 30:1834–1837
DOI 10.1007/s00134-004-2233-5

BRIEF REPORT

Marc Feissel
Frédéric Michard
Jean-Pierre Faller
Jean-Louis Teboul

The respiratory variation in inferior vena cava diameter as a guide to fluid therapy

Received: 12 November 2003
Accepted: 9 February 2004
Published online: 25 March 2004
© Springer-Verlag 2004

An editorial regarding this article can be found at http://dx.doi.org/10.1007/s00134-004-2302-x

M. Feissel · J.-P. Faller

Abstract *Objective:* To investigate whether the respiratory variation in inferior vena cava diameter (ΔD_{IVC}) could be related to fluid responsiveness in mechanically ventilated patients. *Design:* Prospective clinical study. *Setting:* Medical ICU of a non-university hospital. *Patients:* Mechanically ventilated patients with

than in non-responders (25±15 vs 6±4%, $P<0.001$), closely correlated with the increase in cardiac output ($r=0.82$, $P<0.001$), and a 12% ΔD_{IVC} cut-off value allowed identification of responders with positive and negative predictive values of 93% and 92%, respectively. *Conclusion:* Analysis of ΔD_{IVC} is a simple and non-invasive method to detect fluid

Feissel M, Intensive Care Med (2004) 30:1834–1837

23

12%の変化率がカットオフ

12% DDIVC cut-off value

陽性的中率: 93%
陰性的中率: 92%

Feissel M, Intensive Care Med (2004) 30:1834–1837

24

適応のLimitation

人工呼吸器が装着されていること
1回換気量は 8-10 mL/kg
自発呼吸が無いこと
Sinus Rhythm

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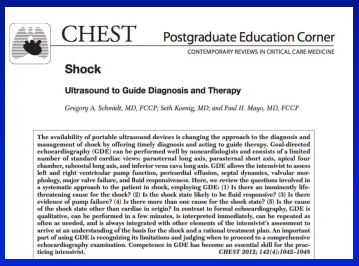
自発呼吸でのエビデンスはあるの？ Expert Opinion: CHEST 2012



CHEST Postgraduate Education Corner
CONTEMPORARY REVIEWS IN CRITICAL CARE MEDICINE

Shock

Ultrasound to Guide Diagnosis and Therapy

Gregory A. Schmidt, MD, FCCP; Seth Koenig, MD; and Paul H. Mayo, MD, FCCP

The availability of portable ultrasound devices is changing the approach to the diagnosis and management of shock by offering timely diagnosis and aiding to guide therapy. Goal-directed echocardiography (GDE) can be performed well by noncardiologists and consists of a limited number of standard cardiac views: parasternal long axis, parasternal short axis, apical four chamber, subcostal long axis, and inferior vena cava long axis. GDE allows the intensivist to assess left and right ventricular pump function, pericardial effusion, septal dynamics, valvular morphology, major valve failure, and fluid responsiveness. Here, we review the questions involved in a systematic approach to the patient in shock, employing GDE: (1) Is there an imminently life-threatening cause for the shock? (2) Is the shock state likely to be fluid responsive? (3) Is there evidence of pump failure? (4) Is there more than one cause for the shock state? (5) Is the cause of the shock state other than cardiac in origin? In contrast to formal echocardiography, GDE is qualitative, can be performed in a few minutes, is interpreted immediately, can be repeated as often as needed, and is always integrated with other elements of the intensivist's assessment to arrive at an understanding of the basis for the shock and a rational treatment plan. An important part of using GDE is recognizing its limitations and judging when to proceed to a comprehensive echocardiography examination. Competence in GDE has become an essential skill for the practicing intensivist.

CHEST 2012; 142(4):1042-1048

Schmidt GA, Koenig S, Mayo PH, CHEST 2012; 142 (4):1042–1048

26

自発呼吸でのExpert Opinion 1 cm未満で輸液、2.5 cm以上で控える

If the patient is breathing spontaneously or on a ventilator but making respiratory effort, the authors use the following pragmatic approach to identify fluid responsiveness in the patient in shock:

1. If the left ventricle is hyperdynamic with end-systolic effacement, there is a high probability of fluid responsiveness.
2. If the IVC is < 1 cm in diameter, there is a high probability of fluid responsiveness.
3. If the IVC is > 2.5 cm in diameter, there is a low probability of fluid responsiveness.
4. If the IVC is between 1 and 2.5 cm, there is an indeterminate probability of fluid responsiveness.

Schmidt GA, Koenig S, Mayo PH, CHEST 2012; 142 (4):1042–1048

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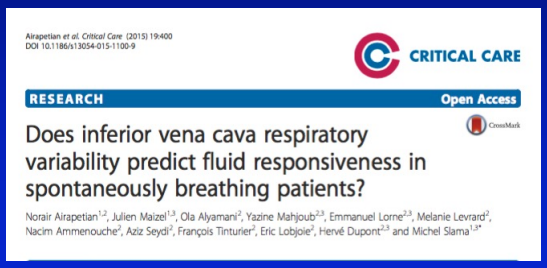
自発呼吸の患者さんでのエビデンス



Airapetian *et al. Critical Care* (2015) 19:400
DOI 10.1186/s13054-015-1100-9

CRITICAL CARE

RESEARCH Open Access

Does inferior vena cava respiratory variability predict fluid responsiveness in spontaneously breathing patients?

Norair Airapetian[1,2], Julien Maizel[1,3], Ola Alyamani[2], Yazine Mahjoub[2,3], Emmanuel Lorne[2,3], Melanie Levrard[2], Nacim Ammenouche[2], Aziz Seydi[2], François Tinturier[2], Eric Lobjoie[2], Hervé Dupont[2,3] and Michel Slama[1,3*]

Airapetian et al. Critical Care (2015) 19:400

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自発呼吸：輸液反応性の予測

Table 5 Accuracy of cIVC at baseline, IVCmax and ΔCO after PLR for predicting fluid responsiveness

	Se	Sp	LR+	LR-	PPV	NPV
cIVC > 42 %	31 %	97 %	9	0.7	90 %	59 %
IVCmax at baseline < 2.1 cm	93 %	33 %	1.4	0.2	57 %	83 %
ΔCO > 10 %	52 %	87 %	4	0.6	79 %	65 %

ΔCO change in CO between baseline and after PLR, *cIVC* collapsibility index at baseline, *IVCmax* maximum diameter of the IVC, *PLR* passive leg raising, *Se* sensitivity, *Sp* specificity, *LR* likelihood ratio, *PPV* positive predictive value, *NPV* negative predictive value

Airapetian et al. Critical Care (2015) 19:400

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HypovolemiaとIVCの評価：まとめ

(1) 右房圧 ≠ 輸液反応性 (Marik 2008)
(2) 目の前の患者さんは挿管されている？自発呼吸？

挿管されている：変化率 12% がカットオフ (Feissel 2004)
自発呼吸：最大径 2.1 cmより大きい→ 輸液に反応しない (Airapetian 2015)
自発呼吸：変化率 42% 以上 → 輸液に反応するだろう (Airapetian 2015)
自発呼吸：最大径 1 cm 未満 → 輸液に反応するだろう (Airapetian 2015, Schmidt 2012)
Expert Opinion (2.5 cm, 1 cm)→ 実は悪くない? (Schmidt 2012)

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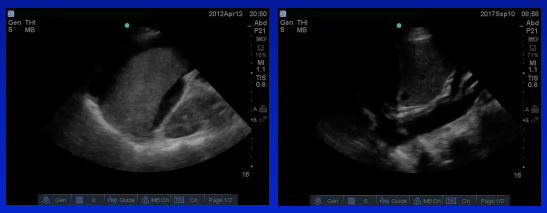
Hypervolemia
その他のエコーの所見: 心臓エコー

左室: 過収縮
(Hyperdynamic LV,
Kissing ventricle)

右室: 正常 or 内腔サイズ
減少

31

Hypovolemia:
その他のエコーの所見: 出血のサインは？



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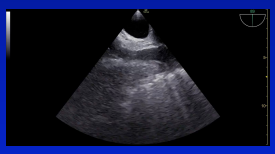
輸液反応性について
Beyond POCUS: TEEとSVC



ΔPP ΔVmaxAo ΔSVC ΔIVC

ΔVmaxAo had the best sensitivity and

ΔSVC the best specificity in predicting fluid responsiveness.

ΔSVC had a greater diagnostic accuracy than ΔIVC and ΔPP, but its measurement requires transesophageal echocardiography.

Vignon PA et al. Comparison of Echocardiographic Indices Used to Predict Fluid Responsiveness in Ventilated Patients. Am J Respir Crit Care Med. 2017 Apr 15;195(8):1022-1032.

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ショックと心臓の収縮能

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Cardiogenic Shockの評価

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Modified from Lacticova V, Narasimhan M, Hypotension and Shock in Soni N, Arntfield R, Kory P ed. Point-of-Care Ultrasound 2015

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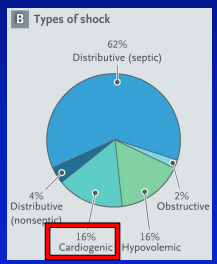
Cardiogenic Shock



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Vincent JL, De Backer D. Circulatory shock. N Engl J Med. 2013 Oct 31;369(18):1726-34

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LV systolic function
量的評価

Quantitative Assessment
(1) Fraction Shortening (FS)
(2) Ejection Fraction (EF)
(3) Stroke Volume (SV)

Normal Value (EF)
Man: 52-72%
Woman: 54-74%

© Bannerman (Edited by Chi-Chi)

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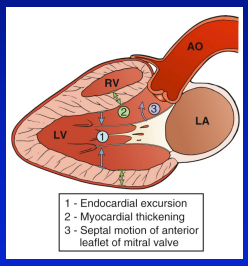
LV systolic function
質的評価



Qualitative assessment, not quantitative (such as ejection fraction)
(1) Endocardial Excursion
(2) Myocardial thickening
(3) Septal motion of anterior leaflet of mitral valve

Soni, N et al: Point-of-Care Ultrasound 2nd Edition, Elsevier, 2019

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FoCUS to detect LV dysfunction
質的評価は使えるの？

To detect LV systolic dysfunction
Sensitivity: 73 - 100%
Specificity: 64 - 96%
"Most importantly, although the ability to detect abnormalities at the bedside by FCU users is lower than having a comprehensive TTE, **it is clearly better than traditional bedside assessment**"

J Am Soc Echocardiogr 2013;26:567-81

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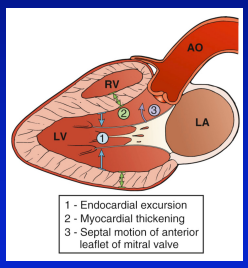
心臓の収縮能：チェックリスト



[ ] Endocardial Excursion
[ ] Myocardial thickening
[ ] Septal motion of anterior leaflet of mitral valve

40

評価は?

41

評価は？

[ ] Endocardial Excursion
[ ] Myocardial thickening
[ ] Septal motion of anterior leaflet of mitral valve

42

評価は？

[y] Endocardial Excursion
[y] Myocardial thickening
[y] Septal motion of anterior leaflet of mitral valve

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心原性ショックの可能性　低

[y] Endocardial Excursion
[y] Myocardial thickening
[y] Septal motion of anterior leaflet of mitral valve

44

評価は?

[ ] Endocardial Excursion
[ ] Myocardial thickening
[ ] Septal motion of anterior leaflet of mitral valve

45

評価

[n] Endocardial Excursion
[n] Myocardial thickening
[n] Septal motion of anterior leaflet of mitral valve

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心原性ショックの可能性あり

[n] Endocardial Excursion
[n] Myocardial thickening
[n] Septal motion of anterior leaflet of mitral valve

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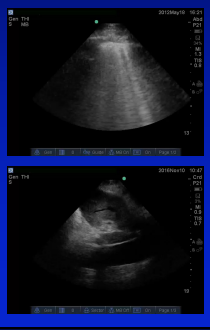
組み合わせに注意



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ショックと心臓の収縮能：まとめ

EFよりも、以下のポイントに注目

[ ] Endocardial Excursion

[ ] Myocardial thickening

[ ] Septal motion of anterior leaflet of mitral valve

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Beyond POCUS
Stroke Volume Calculation

SV = CSA x VTI

CSA: Parasternal Long Axis View

VTI: Apical 5 chamber view

Accurate measurement of LVOT Diameter (Aortic Annular Diameter) is a key (Mid-systole, Inner-edge to Inner-edge)

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Obstructive shockの評価

	循環血漿量減少性	心原性	閉塞性	血液分布異常性
IVC	Collapsed	Distended	Distended	lormal/ Collapsed
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Modified from Lacticova V, Narasimahn M, Hypotens... N, Arntfield R, Kory P ed. Point-of-Care Ultrasound 2015

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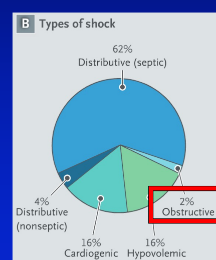
Obstructive Shock



Distributive (sepsis) 62%

Hypovolemic 16%

Cardiogenic 16%

Distributive (nonseptic) 4%

Obstructive 2%

Vincent JL, De Backer D. Circulatory shock. N Engl J Med. 2013 Oct 31;369(18):1726-34

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Obstructive shock: 鑑別疾患

Tension pneumothorax

Pericardial Tamponade

Pulmonary embolism

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Obstructive shock: Checklist

[ ] Sliding Lung? (Lung US/ BLUE)

[ ] Pericardial effusion? (FoCUS)

[ ] RV? (assess for PE) (FoCUS)

[ ] DVT? (assess for PE) (BLUE)

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First, rule out pneumothorax

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鍵となる所見: Lung Sliding

存在すれば: 気胸はなし
存在しないと: 臓側胸膜が壁側胸膜に対し

1) スライドしていない
   1) 急性・慢性の癒着、無気肺、無呼吸
2) 分離している
   2) 気胸、肺切除後

Lichtenstein DA, CHEST 2008; 134:117–125

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Lung Sliding無し ≠ 気胸

存在すれば: 気胸はなし
存在しないと: 臓側胸膜が壁側胸膜に対し

1) スライドしていない
   1) 急性・慢性の癒着、無気肺、無呼吸
2) 分離している
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Lichtenstein DA, CHEST 2008; 134:117–125

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Lung sliding and A lines

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Thrombosed Vein

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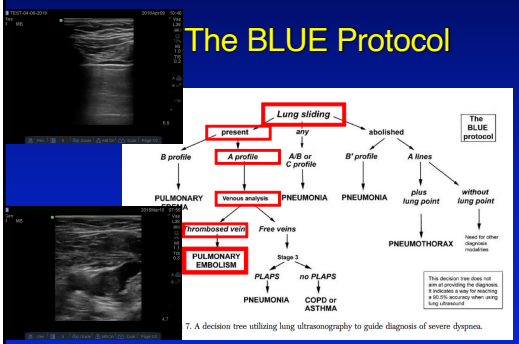
The BLUE Protocol



Lichtenstein DA, CHEST 2008; 134:117–125

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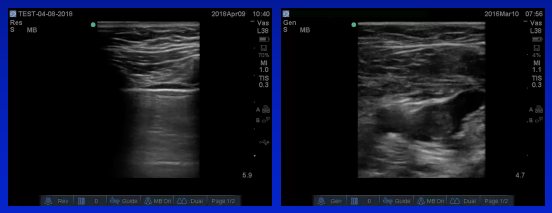
A profile + DVT: Pulmonary Embolism
Sens: 81%, Spec: 99%



Lichtenstein DA, CHEST 2008; 134:117–125

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Case: Rapid Responseで呼ばれました

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Obstructive Shock

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肺塞栓症 → 心停止

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Obstructive Shockのサインは？

右室は拡大してないようだけれど・・・

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Obstructive Shockのサインは？

右室は拡大してないようだけれど・・・

タンポナーデ？

- RV diastolic collapse
- RA systolic collapse
- Restrictive physiology

迷ったら専門医を！

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Distributive shockの評価

	循環血漿量減少性	心原性	閉塞性	血液分布異常性
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Modified from Lacticova V, Narasimahn M, Hypotension and Shock in Sc
R, Kory P ed. Point-of-Care Ultrasound 2015

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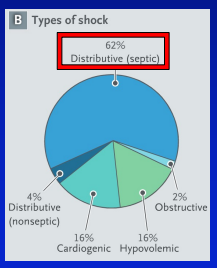
Distributive Shock: 62+4 = 66%



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Distributive Shock

IVCを見てもHypovolemiaはなさそう
心エコーでもCardiogenic Shockもなさそうで
立派なLung Slidingもある。心嚢液もない。
Distributive Shockか？

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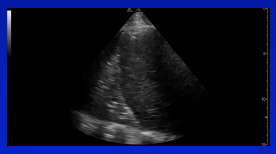
Distributive Shock
原因を探しましょう

水はどこ・・・？

肝臓かな・・・？



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Distributive Shock
原因を探しましょう

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まとめ：その1
ショックの原因には4つある

循環血液量減少性 (Hypovolemic)
心原性 (Cardiogenic)
閉塞性 (Obstructive)
血液分布異常性 (Distributive)

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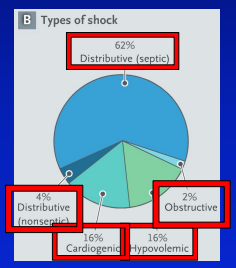
まとめ その2:
Think about probability



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まとめ その3 画像を組み合わせる

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Modified from Lacticova V, Narasimhan M, Hypotension and Shock in Soni N, Arntfield R, Kory P ed. Point-of-Care Ultrasound 2015

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ご静聴誠に有り難うございました

南太郎
Taro Minami, MD

ご質問あればお気軽に！
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nantaro@gmail.com
taro_minami@brown.edu

Robert Thom, Laennec and the Stethoscope, courtesy of University of Michigan Museum of Art

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