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Early-Detection Pediatric Sepsis Algorithm

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COMMIMENT

Session #29: March 6, 2018

Boston Children's Hospital



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Conflict of Interest

Statistical and project management support for this study were provided by an electronic medical record vendor

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Agenda

- Background
- Creating a pediatric sepsis detection
 algorithm
- Algorithm performance
- Implementation into clinical workflows
- Future directions



Learning Objectives

- Recognize the process used to develop and evaluate the pediatric sepsis algorithm at Boston Children's Hospital
- Describe the range of operating characteristics of the pediatric sepsis algorithm based on different changes to the algorithm
- Identify the strategy for inserting the algorithm into clinical workflows
- Discuss the plans to iterate on the algorithm moving forward



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Background

• Pediatric vs. adult sepsis

 Quality improvement efforts in pediatric sepsis



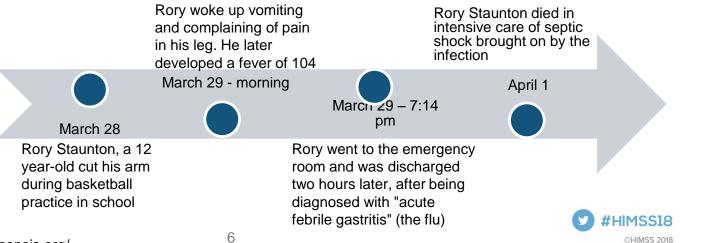
Source: <u>www.childrenshospitals.org</u> 2017 Childrens' Hospital Photo Exhibit

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https://rorystauntonfoundationforsepsis.org/

Pediatric Sepsis

- 4,000 children die annually of sepsis in the U.S.
 - more than cancer (~1,800) or gun violence (~1,700)
- #1 cause of mortality in children worldwide
- Adults vs. Kids
 - Adult sepsis criteria SCCM/ES-ICM Sepsis 3 (JAMA 2016)
 - Defines sepsis with organ dysfunction
 - Organ dysfunction not a sensitive sign in pediatrics
 - Children develop shock later in course



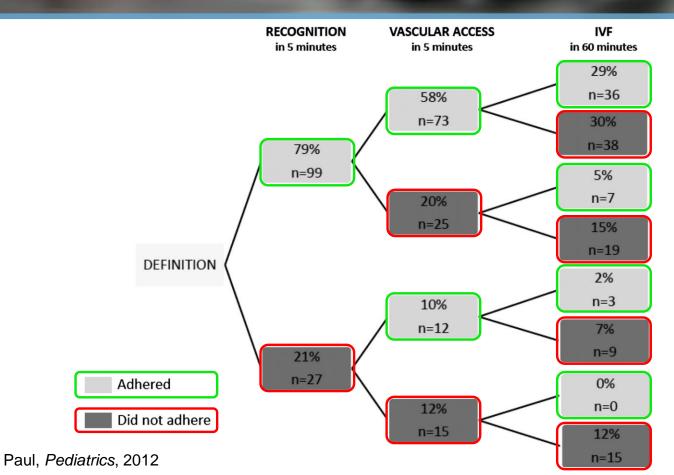
The Challenge of Recognition Adults Children

- Sepsis identification tools based on one set of criteria
- Organ dysfunction included in sepsis definition
- Hypotension an earlier sign

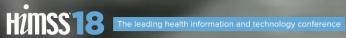
- Vital sign & lab criteria differ based on age groups
- Tools must incorporate many different age-based cutoffs
- Organ dysfunction a later sign
- Hypotension occurs late



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Care Element	Pre-intervention Adherence, <i>n</i> (%)	Post-intervention Adherence, <i>n</i> (%)	<i>P</i> Value
Recognition within 5 min	180 (79)	113 (97)	.011
Vascular access within 5 min	84 (67)	104 (90)	<.001
60 mL/kg IV fluid within 60 min	47 (37)	85 (73)	<.001
Antibiotics within 60 min	88 (70)	99 (86) 🗙	.02
Vasoactive agents started at 60 min	44 (35)	79 (68)	<.001
Overall bundle adherence	24 (19)	90 (78)	<.001
Appropriate fluid mechanism used (pressure bag, rapid-infuser, manual push)	62 (49)	110 (95)	<.001
(pressure bag, rapid-infuser, manual	62 (49) 10	110 (95)	<.0

Paul, Pediatrics, 2014

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Algo	rithmic A	lert	Physi	cian Judge	ement (PJ)	Combination		
	Severe Sepsis +	Severe Sepsis -		Severe Sepsis +	Severe Sepsis -		Severe Sepsis +	Severe Sepsis -
Alert +	81	3,220	PJ +	64	95	Either +	85	3,249
Alert -	7	16,216	PJ -	24	19,341	Both -	3	16,187
Sum	88	19,436		88	19,436		88	19,436
PPV	2.	.5		40.3		Either +	2.6	
Sensitivity	92	2		73		Either +	97	

• Proportion of all patients with a positive screen for potential sepsis

- algorithmic alerts 16.9% (3,301)
- physician judgment (PJ) 0.8% (159)
- combined either positive 17.1% (3,334)

Balamuth, Acad Emerg Med, 2015



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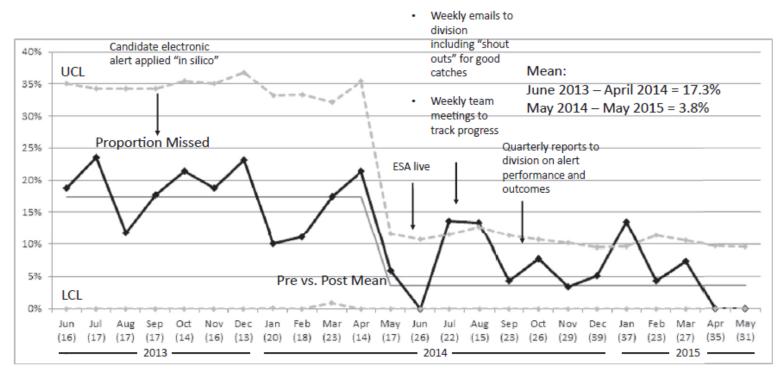
2 Step Alert Process

Practice Advisory - TeeSystem, Marylo	
TV Your patient has tachycardia and/or hypotension documented.	
Filed Sepsis-Related Vitals: 03/24/15 1221	
Pulse: 200 Additional assessments are needed to determine further interventions.	
Is there a fever (home or ED >= 38), hypothermia or signs/symptoms of infection for this pati	Sepsis Screen - Sepsis Screen
Do one of the following: If No , click the no concern for infection button below.	Time taken: 1938 0 5/13/2014 Show: Row Info Last Filed Details
If Yes, click the hyperlink below to document additional assessments.	Values By Create Note
Acknowledge reason: 20 C	
No concern for infection	UE Cap Refill 2-3 seconds > 3 seconds
5 CLICK HERE TO DOCUMENT ADDITIONAL ASSESSMENTS	Existing High Risk C < 56 Days Old
	Condition Asptenia
Accept & Stay Accept	Bone Marrow or Solid Organ Transplant
	Central Line
	Malignancy
	Significant CNS/Functional Tech Dependence
	Other Immunodeficiency/Immunocompromise
	None
	🕅 Restore 🕑 Close F9 🗙 Cancel 🛉 Previous F7 🚽
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Balamuth, Annals of Emerg Med, 2017



Outcome measures - sepsis mortality - rapid transfers and bounce backs	Process measures - initial clinical assessment - timely first and third bolus - timely antibiotics - timely transfer to ICU
Balancing measure - false positive rate	<u>Supplemental measures</u> - hospital LOS - ICU LOS - days on vasopressors - lab bundle obtained (cbc, lactate, blood cx)





Creating a Pediatric Sepsis Detection Algorithm

Algorithm creation

• Defining sepsis "gold standard"





Source: <u>www.childrenshospitals.org</u> 2017 Childrens' Hospital Photo Exhibit



Project Goal

- Develop an automated sepsis screening tool to alert clinicians of children at risk of severe sepsis
 - Earlier detection \rightarrow more rapid intervention
 - Prevent missed cases





Partnering with the Vendor

- Vendor had pre-existing adult sepsis screening tool
 - Not designed for use in children
- Vendor team
 - Performance improvement strategists
 - Statisticians
- BCH team
 - Critical care and emergency medicine physicians



Challenges

- Difficult to distinguish sepsis from vital signs/labs alone
 - Most detection tools have low specificity
 - High risk of alarm fatigue
- Sepsis and severe sepsis are not easily defined
 - Gold standard needed to evaluate tool performance
 - Diagnosis codes inaccurate





Methods

- Alerts based on accepted vital sign and lab values* for:
 - Systemic inflammatory response syndrome (SIRS)
 - Sepsis
 - Severe sepsis/Septic shock
- Run tool in silent mode for 5 months
- Compare silent "alerts" to pre-defined gold standard cohort to assess/maximize tool performance





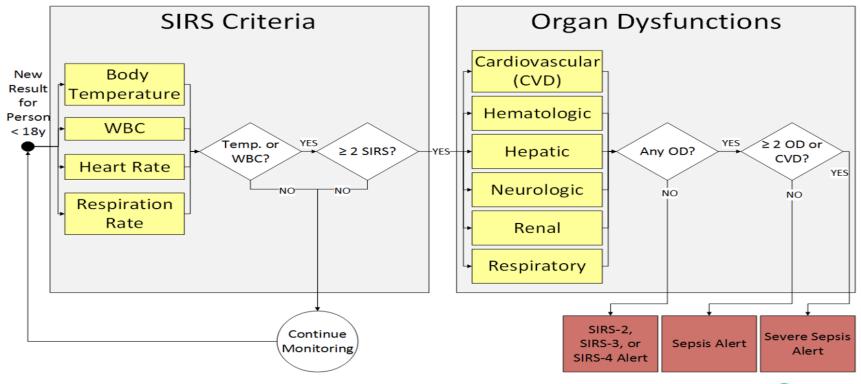
Alert Levels:

- SIRS alert: 2, 3 or 4 SIRS criteria without organ dysfunction
- Sepsis alert: SIRS with 1 organ dysfunctions (non-cardiac)
 - Suspected infection planned for future eval
- Severe sepsis: SIRS and cardiac dysfunction or 2 other organ dysfunctions



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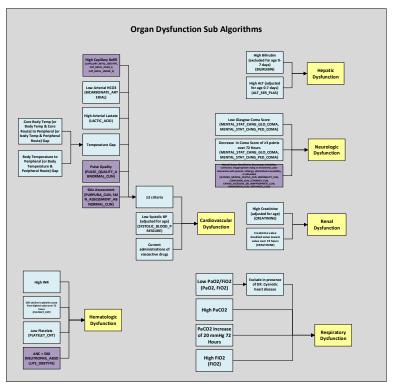
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Defining Organ Dysfunction

- Cardiovascular
 - Hypotension <u>or</u> vasoactive drug <u>or</u>
 - - ≥2 of: acidosis, elevated lactate, oliguria, prolonged capillary refill, core → peripheral temp gap
- Respiratory: Hypoxia, hypercarbia, ventilator support
- Neurologic: Altered mental status
- Hematologic: Low platelets, elevated INR
- Renal: Elevated creatinine
- Hepatic: Elevated bilirubin or ALT





Defining gold standard sepsis cohort

• No single test defines sepsis

• ICD codes are inaccurate

- Defined gold standard by clinician "intention to treat" severe sepsis
 - Also adopted by IPSO sepsis collaborative



Defining severe sepsis

- Patient with suspected infection (SI)
 - SEPSIS-3* Criteria: Blood culture within 72 hours before/24 hours after IV antibiotic

<u>AND</u>

- One of the following between 4 hours before and 6 hours after SI
 - ≥35 cc/kg or 2 L or 2 boluses of isotonic IVF within 2 hours
 - or IV vasopressor
 - or transfer to ICU

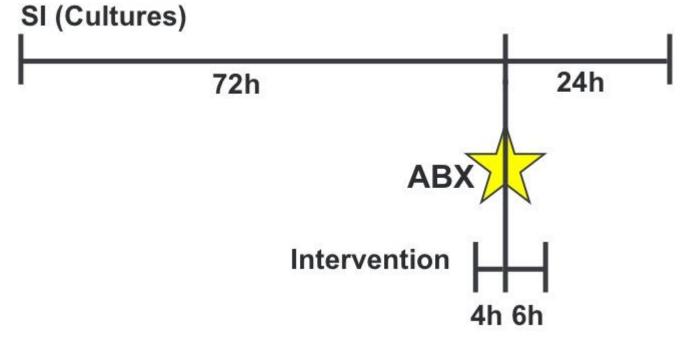
*Singer, JAMA, 2016



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Intention to Treat





Defining severe sepsis

- To ensure no missed cases, also reviewed all charts of:
 - Patients with diagnosis code for severe sepsis or septic shock
 - Patients who died and had diagnosis code for infectious disease



Results: Data set

- All Inpatient and ED encounters over 5 months in 2016
 - 31,286 encounters
 - 22,766 unique persons
- Excluded neonatal ICU
 - Neonatal sepsis is different entity, has different definitions
 - Excluded both alerts and episodes of sepsis that occurred in NICU
 - Exception: patient alerted in another location (e.g. ED) then transferred to NICU





Results: Gold Standard Cohort

- 342 patient encounters (1.5%) met gold standard
 - Intention to treat: 335 encounters
 - Severe sepsis diagnosis code: 7 unique encounters
 - Death with infectious disease diagnosis code: 0 unique encounters



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Algorithm Performance

- Performance of the initial algorithm
- Iterations to improve performance
- Final performance characteristics

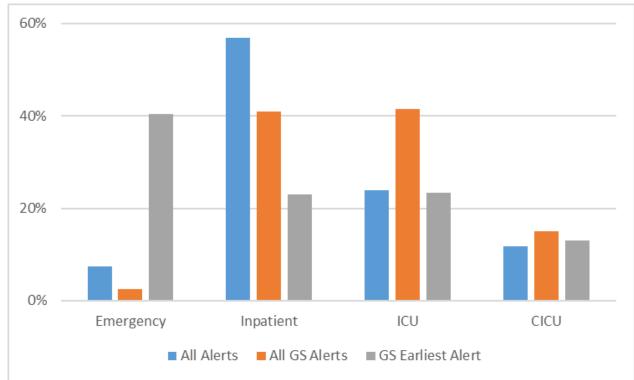


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Alert location on patient & encounter level

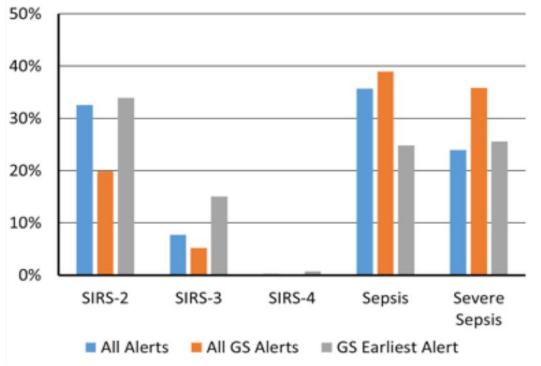


GS alerts = alert within 48 hours of meeting "gold standard" for sepsis



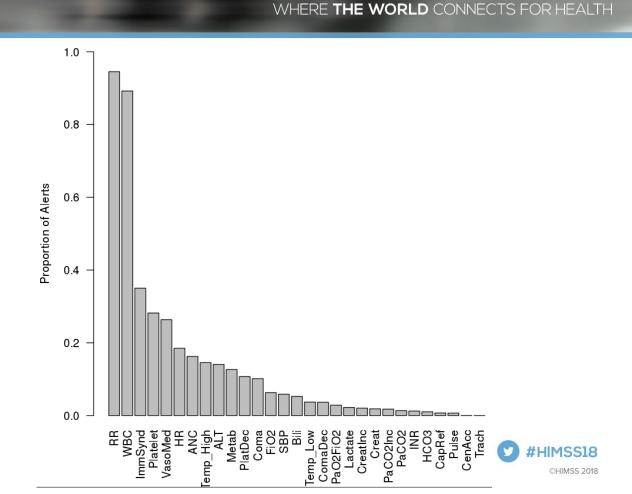


Alert by severity level





Contribution of variables to alerts



H2M

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Iterations of algorithm analyzed

- Goldstein reference ranges
- Different respiratory rate ranges:
 - No Respiratory Rates
 - 25% and 50% increases in Goldstein RR ref. ranges
 - 25% and 50% increases in Goldstein RR ref. ranges without SIRS-2 alerts
 - Bonafide 75th, 80th, 85th and 90th percentile RR for ref. range cutoffs

- Different lookback periods
 - HR AND Temp within 30 minutes of each other
 - Temp. 4h, blood gases 6h, other labs 24h
- Different SIRS variables
 - No SIRS-2 alerts
 - Restrictive SIRS
- Different iterations of bands:
 - Immature Granulocytes instead of bands
 - No bands

Goldstein, Pediatr Crit Care Med, 2005; Bonafide, Pediatrics, 2013





Alternate Vital Sign Criteria

Age Groups	Goldstein RR	Bonafide 75% RR	Bonafide 95% RR
0-6 days	50	48	62
7-29 days	40	48	62
1 month - 1 year	34	40	51
2-5 years	22	30	40
6-12 years	18	26	33
13-17 years	14	21	27

Goldstein, Pediatr Crit Care Med, 2005; Bonafide, Pediatrics, 2013





Test Characteristics of Alert Iterations

Metric	Goldstein	Bonafide	Bonafide	No RR	No
		75%	95%		SIRS-2
Sensitivity	87.7%	83.9%	80.4%	75.4%	79.8%
Specificity	86.9%	91.4%	93.2%	94.2%	92.8%
PPV	9.2%	13.0%	15.2%	16.5%	14.4%
Person Alerts (%)	14.2%	9.7%	7.9%	6.8%	8.3%





Unit specific performance

Emergency Department

Intensive Care Unit

Alert	#	# Alerted		Alert	#	# Alerted	
Severity	Alerts	Persons	PPV	Severity	Alerts	Persons	PPV
SIRS	1,157	1,085	9%	SIRS	424	228	12%
Sepsis	136	115	20%	Sepsis	384	177	12%
Severe Sepsis	104	95	36%	Severe Sepsis	767	234	27%
All	1,397	1,213	12%	All	1,575	443	19%

PPV in other inpatient services 5%





Implementation into Clinical Workflows

Current state

• Implementation in the emergency department



Source: <u>www.childrenshospitals.org</u> 2017 Childrens' Hospital Photo Exhibit



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Current state of sepsis process

- Sepsis screening tool
 - Emergency department: embedded in EHR
 - Rest of hospital: paper form
- Sepsis/septic shock order sets
- Tracking board icons: ED only
- Sepsis huddles
- QI: Education/socialization, PDSA cycles, measurement

Image: Second	//05/17	EDT		By: CAPRARO MD, ANDREW J
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		O >6yr-13y, >30		
	Cap refil	O Normal	C Abnormal	
	Mental status	O Normal	C Abnormal	Decreased, irritable, confused, inappropriate crying or drowsiness, poor
Ware manor quanty Ware mail dock: bounding Named	- and status			interaction with parents, lethargy, diminished arousability, obtunded
All Anter Control Contron Control Control Control Control Control Control Control Control	Pulse quality	C Normal	C Abnormal	
flabled ruddy, eryferoderna offer than face (warn shock) face of the factors for Sepsis O Yee O No O Yee	Skin	C Normal	C Abnormal	Petechiaw below nipple, any purpura, motiled and cool (cold shock);
schattors for Sepses solid organ transplant, severe MR/CP, immunodeficiency/immunouppression fiscore >3, notify charge nurse and call team attending or 5-1902 for	- Shar			flushed ruddy, erythroderma other than face (warm shock)
If score >3, notify charge nurse and call team attending or 5-1802 for	Risk Factors for Sepsis	O Yes	O No	Malignancy, asplenia, bone marrow transplant, central or indwelling line/catheter, solid organ transplant, severe MR/CP, immunodeficiency/immunosuppression
	Property		-	
	score:			evaluation.

Caution: alert fatigue

- Children frequently have abnormal vital signs when febrile, scared or in pain
 - Few of these children actually have severe sepsis
- Most children with severe sepsis are identified by clinicians
 - "Added value" of alert can be low
- Risk of alert fatigue is high



Caution: alert fatigue

- Recent study of an electronic sepsis surveillance system in an adult ER showed high alert fatigue and no improvement in outcomes
 - Sensitivity of alert 80%; PPV 15%
- Alert fatigue
 - Only two-thirds of patients with documented sepsis had a clinician respond to the alert
 - >20% of patients with sepsis had a clinician respond that sepsis was not present





How to reconcile

- Alerts are important but PPV is low
- Clinician judgment still necessary
 - Healthy vs. immunocompromised
 - "Sick" vs. "Not sick"
- Solution in BCH ED: 2 stage process
 - SIRS or Sepsis alert \rightarrow secondary screen
 - Severe sepsis alert (higher PPV): sepsis huddle



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Stage 1: Automated Alert



+SIRS/SEPSIS ALERT

- Alert goes to attending, trainee and RN assigned on tracking board
- No assignment → Any RN with "relationship"

Task Edit View Help	
📕 🗅 🔩 😒	
Subject	Event Date/Time
Sepsis Alert	11/13/17 15:56:20
Severe Sepsis Alert	11/13/17 15:50:33
SIRS Alert	11/13/17 11:10:56
🖬 🕰 🥌 🗟 🗟 🔍 🔍 100	% ▼ 0 0 2 4
DISCERN ALERT	
NAME: SABINO, BUILD JOWELL	
DATE: November 13, 2017 15:50:33 E	IST
MRN: 761-12-63	
BIRTH DATE: January 01, 2000	
AGE: 17 Years	
LOCATION: Boston Children's Hospit SEVERE SEPSIS ALERT:	al; Emergency Department; 06
* Your patient meets criteria for SEVER.	E SEPSIS or SEPTIC SHOCK
* Please notify the attending caring for th	
SEPSIS HUDDLE at the patient's bedsi	de.
Click here to open patient chart.	
SIRS Criteria	
11/13/17 14:04:00 Heart Rate = 100 bp	m (L) [greater than or equal to 95]
11/13/17 15:50:00 Temperature = 41 C	
11/13/17 14:04:00 Respiratory Rate = 2 22]	5 bpm (H) [greater than or equal to
Organ Dysfunction	
11/13/17 15:30:00 Systolic Blood Press to 90]	ure = $\$\$$ mmHg (L) [less than or equal
Ready	B647 EDMD EDMD Monday





Stage 2: Active Screening



+SIRS/SEPSIS ALERT

Discern Notification (EDMD) Tak Edit View Help Subject Subjec

■ 2. 3 # 3 3 3 4 4 100% • 0 0 2 4

DISCERN ALERT

NAME: SABINO, BUILD JOWELL DATE: November 13, 2017 155033 EST MRN: 761-126 BIRTH DATE: Jamary 01, 2000 AGE: 17 Yeas LOCATION: Bostos Chibten's Hosphal, Emergency Department; 06 STVERE SEPSEN LLERT:

 Your patient meets criteria for SEVERE SEPSIS or SEPTIC SHOCK
 Please notify the attending caring for the patient immediately and perform a SEPSIS HUDDLE at the patient's bediside.
 Click here to open patient chart.

SIRS Criteria

11/13/17 14/4000 Heart Rate = 100 Span (L) [greater than or equal to 55] 11/13/17 15/50/00 Temperature = 41 C (H) [greater than or equal to 38.3] 11/13/17 14/40/00 Respiratory Rate = 25 bpm (H) [greater than or equal to 22] Organ Dysfunction 11/13/17 15/50/00 Systolic Blood Pressure = 88 mmHg (L) [less than or equal to 50]

Ready B647 EDMD EDMD Monday

Discern Notification (EDMD)

RN Fills out Sepsis Screen



Active Screen

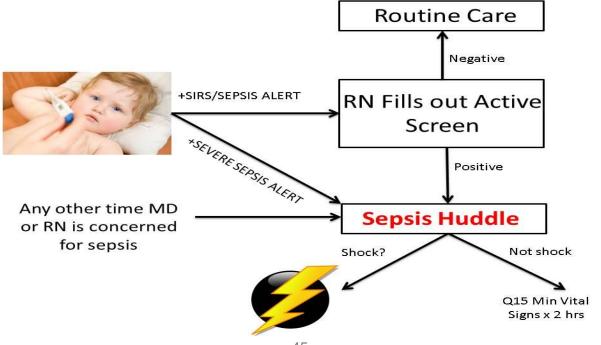
- Link within discern notification to clickable form
- <u>Question 1:</u> Does patient have fever or do you suspect infection
 - − If no \rightarrow form closes
 - If yes \rightarrow answer question 2
- <u>Question 2:</u> Does the patient have any of the following:
 - Immuno-compromise or high risk of sepsis (e.g. CVL)
 - Altered mental status
 - Altered pulses/perfusion
- "Positive screen" if yes to both questions



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ED sepsis protocol





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Future Directions

• Project impact and results

• Version 2 and beyond



Source: <u>www.childrenshospitals.org</u> 2017 Childrens' Hospital Photo Exhibit



What's next

- Continued cycles of improvement
- Adding to the model to further improve PPV
 - Risk of infection
 - History of chemo order, indwelling lines
 - Suspected infection
 - Microbial test or antimicrobial given
 - Changes in vital signs



What's next

- Complete ED implementation and evaluate
 - Prospective study ongoing
 - Outcomes: missed cases, timeliness of interventions, ICU LOS, mortality
- Test and apply in other venues within the hospital
 - Different rules based on location
 - ICUs vs inpatient surgical vs medical or oncology
 - Different notification and suppression rules



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Thank you

BCH Team

- Elliot Melendez, MD
- Marvin Harper, MD

EMR Team

- Jeff Christianson, PhD
- Abbey Logan, Strategist
- Justin Kimbrell, Sr. Strategist





Questions

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- Please complete online session evaluation





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