


Heart murmurs and technology: Auscultation in 2009

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Grand Rounds
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Outline

- Background
- Murmur evaluation: current evidence
- Computer-aided auscultation: role?
- Teaching of auscultation: tools for improvement

Objectives

1. Describe an evidence-based approach to murmur evaluation in infants and children
2. Recognize common innocent and pathologic murmurs... audio examples
3. Describe the potential role of software in murmur evaluation & teaching

Background

- “Murmur” = #1 reason for referral to pediatric cardiology clinics
- prevalence in neonates as high as 77%
- prevalence of CHD only 0.4-1.2%
- most children with a murmur are asymptomatic
- may be the only clue to the presence of CHD, including severe lesions

How can the clinician reliably distinguish innocent from pathologic murmurs?

Murmur Characteristics

Innocent	Pathologic
<ul style="list-style-type: none"> • systolic • ejection • soft or vibratory • grade \leq 3 • normal S1 and S2 • no extra sounds • louder supine 	<ul style="list-style-type: none"> • diastolic (e.g. AR, MS) • holosystolic (e.g., MR) • harsh • louder than 3/6 • abnormal S1 or S2 • extra sounds, e.g. click • louder when patient stands



Role of ECG? CXR?

<p><u>ECG</u></p> <ul style="list-style-type: none"> • Pros <ul style="list-style-type: none"> – Noninvasive – Cheap • Cons <ul style="list-style-type: none"> – Insensitive 	<p><u>Chest X-Ray</u></p> <ul style="list-style-type: none"> • Pros <ul style="list-style-type: none"> – Noninvasive – Cheap • Cons <ul style="list-style-type: none"> – Radiation – Insensitive
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DATA??

Role of ECG? CXR?

- Swenson et al.
 - Children’s Hospital of Philadelphia
 - 106 consecutive outpatients, age 1 mo-14 yr
 - Underwent history and physical exam, then...
 - Cardiologist decided either
 - “no heart disease”
 - “possible heart disease”
 - “definite heart disease”
 - CXR and ECG then reviewed

Pediatrics 1997; 99:1-3

Role of ECG? CXR?

- Swenson et al. (cont’d)
 - “No heart disease” in 60 (57%)
 - Of these, 53 (88%) had normal CXR and ECG
 - 5 had abnormal ECG
 - small ASD (n=1) ... RVH on ECG
 - hypertrophic cardiomyopathy (n=1) ... LVH on ECG
 - normal echo (n=3) ... 1 had WPW on ECG
 - 2 had abnormal CXR
 - normal echo (n=1)
 - partial absence of the pericardium (n=1)

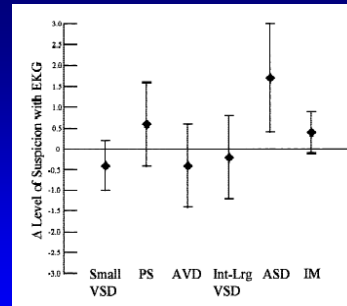
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 - normal echo (n=1)
 - partial absence of the pericardium (n=1)
 - In summary, 4 (7%) picked up by ECG/ CXR

Role of ECG? CXR?

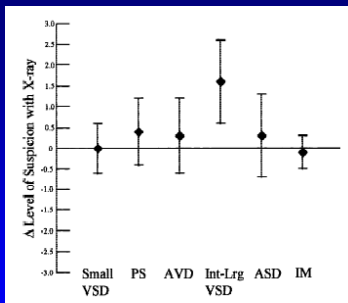
- Danford et al.
 - University of Nebraska
 - 749 outpatients under 21 years, referred to cardiology for evaluation of a heart murmur
 - differential diagnosis recorded prior to echo
 - level of certainty rated on scale of 1-6
 - ECG and CXR done at discretion of cardiologist

Pediatric Cardiology 2000;21:334-340



Use of **ECG** correctly increased the level of clinical suspicion for **ASD**, independent of use of CXR, identity of the examiner, or patient age

Pediatric Cardiology 2000;21:334-340



Use of **CXR** of no real help

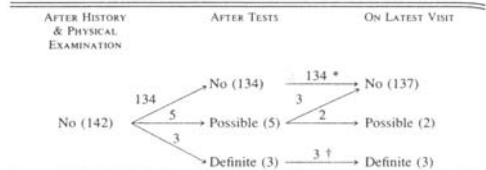
Pediatric Cardiology 2000;21:334-340

Role of ECG? CXR?

- Newburger et al.
 - 280 children 1 mo -18 years referred for murmur evaluation
 - history and physical exam, then diagnosis of:
 - no heart disease
 - possible heart disease
 - definite heart disease
 - ... followed by ECG, CXR, and M-mode echo

NEJM 1983;308:61-4

Table 1. Changes in Heart-Disease Category among Children with No Disease According to History and Physical Examination.



*For 120 of these patients, the initial visit was the latest.
 †For two of these patients, the initial visit was the latest.


NEJM 1983;308:61-4

How good are cardiologists?

- Smythe et al.
 - Children's Hospital of Eastern Ontario
 - 161 children age 1 mo-17 yr for murmur eval
 - History and exam ⇒ ECG ⇒ echo in all
 - **Sensitivity of clinical examination 96%**
 - Missed 1 small ASD and 1 small VSD
 - **Specificity 95%**
 - ECG did not change any clinical diagnosis

Pediatrics 1990;86:497-500

Which clinical signs are most useful??



“Cardinal Clinical Signs”

- McCrindle et al.
 - Johns Hopkins
 - 222 infants and children seen for a murmur
 - clinical findings and impression documented after clinical assessment
 - sensitivity 97%, specificity 98%
 - concluded that routine echocardiography is unnecessary

Arch Pediatr Adolesc Med 1996;150:169-74

“Cardinal Clinical Signs”

- Features independently predictive of CHD:

Clinical sign	OR (95% CI)
Pansystolic murmur timing	54 (6.3-464)
Murmur intensity ≥ 3	4.8 (1.6-14.4)
Maximal intensity LUSB	4.2 (1.9-9.6)
Harsh quality	2.4 (1.0-5.6)
Systolic click	8.4 (2.4-29)
Abnormal S2	4.1 (1.1-15.8)


Arch Pediatr Adolesc Med 1996;150:169-74

What about neonates?

1. High heart rates... auscultation is difficult
2. Important changes occur in CV system over initial 4-6 weeks of life
 - ⇒ influences the evolution of signs & symptoms of CHD
3. Stakes are high ⇒ serious lesions usually present < 1 month of age

Term newborns

- Montreal Children’s Hospital
 - 201 neonates age 1-31 days
 - History and exam ⇒ ECG ⇒ echo
 - Clinical findings and impression documented



- 113 (56%) had CHD
- Sensitivity 80.5%
- Specificity 90.9%
- ECG of no help

Mackie et al. J Peds 2008

Term newborns

Diagnosis	Echo finding at last f/u	N
Small muscular VSD	Spontaneous closure	8
	Small, no change	1
ASD	Smaller (≤ 4 mm), without RV dilation	3
	Spontaneous closure	2
	No f/u	1
Small PDA	Spontaneous closure	3
	Small, no change	1
	No f/u	1
Pulmonary stenosis	Mild; no change in Doppler gradient	1
Bicuspid aortic valve	No f/u	1

Mackie et al. J Peds 2008

Term newborns

Diagnosis	Echo finding at last f/u	N
Small muscular VSD	Spontaneous closure	8
	Small, no change	①
ASD	Smaller ($\leq 4\text{mm}$), without RV dilation	3
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Mackie et al. J Peds 2008

Newborns- Cardinal Signs

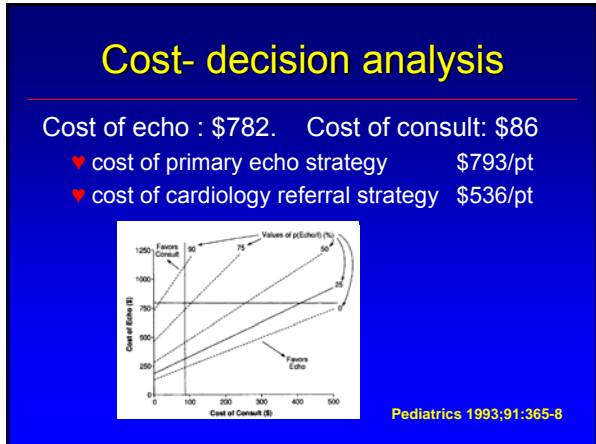
- From clinical assessment, independent predictors of CHD were:

Clinical sign	OR (95% CI)
Harsh quality	9.1 (3.7-22.2)
Loudest location	2.5 (1.2-5.5)
(RUSB, LLSB, or apex)	
Timing	10.4 (1.2-91.7)
(pansystolic, diastolic, or continuous)	

Mackie et al. J Peds 2008

What is the most \$\$ effective method of murmur evaluation?

- ### Cost Effectiveness
- Danford et al.
 - University of Nebraska Medical Center
 - Decision analysis model comparing:
 - Echo first, referral to cardiology if abnormal, vs.
 - Referral to cardiology first, echo at discretion of cardiologist
 - Model incorporated:
 - probability of heart disease
 - frequency of cardiologist-ordered echo
 - echo results
- Pediatrics 1993;91:365-8



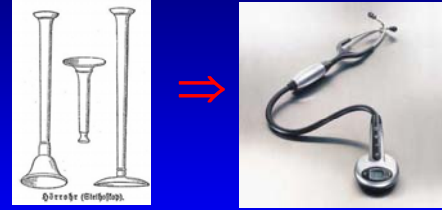
- ### Children in Adult Echo Labs?
- 29/35 patients had altered clinical management after echo in pediatric center
 - 12 operations planned
 - 2 operations averted
 - 3/35 had complications from delay in Dx

Am J Cardiol 1999;83:908-914
 - 25-30% "would not have undergone echocardiography if referred here"

Pediatrics 1998;102:e15

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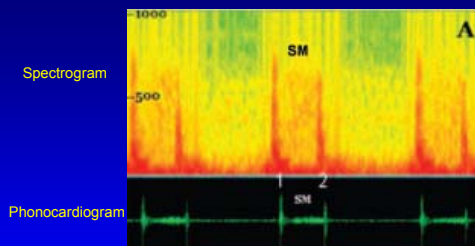
Electronic stethoscopes

- Advantages over mechanical scopes:
 - ✓ Storage and playback of sounds
 - ✓ Slow playback without distortion of sound
 - ✓ Visual display
 - Phonocardiogram
 - Spectrogram
 - ✓ Interpretation of sounds
 - ✓ Transmission to multiple listeners



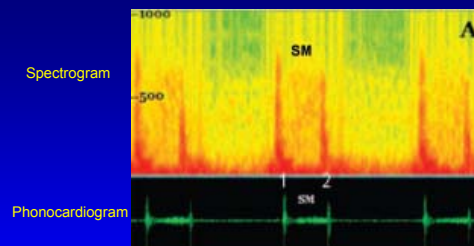
Severe aortic stenosis

Innocent murmur



Spectrogram

Phonocardiogram

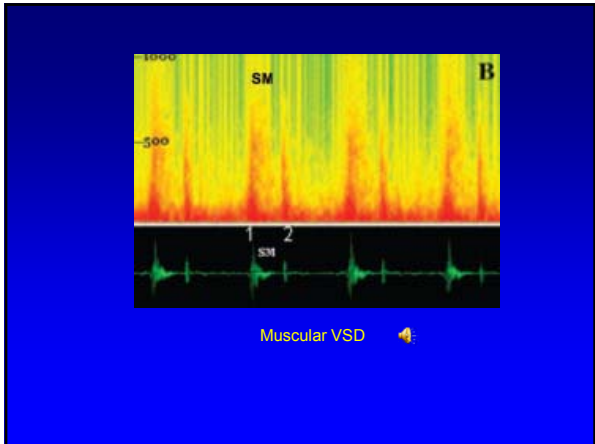


Spectrogram

Phonocardiogram

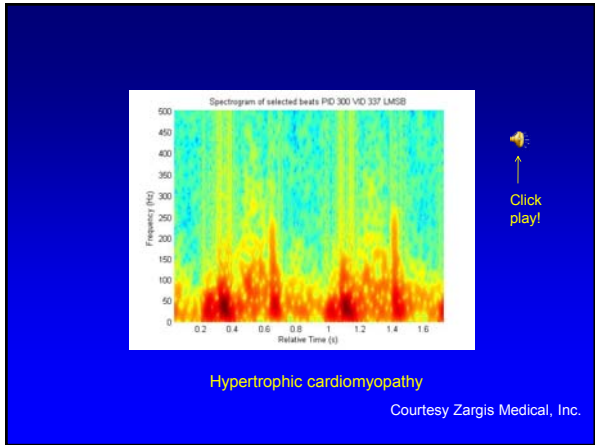
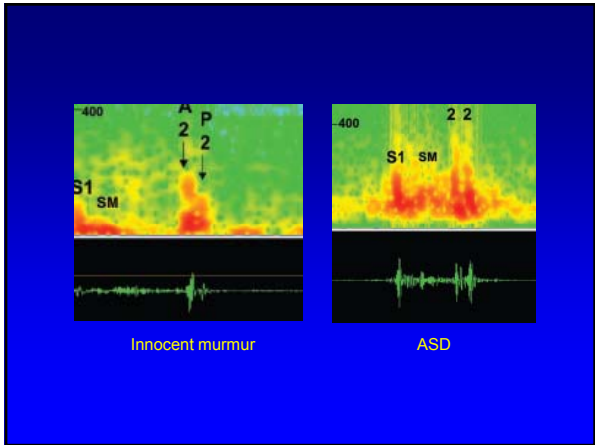
Mitral regurgitation

- ◆ Pansystolic
- ◆ Slowly rising peak frequency within systole
- ◆ Even intensity pattern throughout the frequency range




Advantages of spectral display:

- ✓ Can follow visually while listening (cursor weeps synchronously with sound)
- ✓ Peak frequencies and signal duration at arbitrary frequencies can be measured
- ✓ Averaging over multiple cardiac cycles is possible- reduces noise artifact
- ✓ Data can be stored and used for later comparison



Evaluating computer-aided auscultation

- Cecilia Lee (U of A Medicine 2011)
- Cardioscan™ (Zargis Medical, Inc.)
- Objectives:
 1. Determine sensitivity and specificity of Cardioscan™ for determining innocent vs pathologic murmurs
 2. Can cardiologists distinguish innocent from pathologic murmurs recorded electronically?



Evaluating computer-aided auscultation

- Inclusion criteria
 - murmur
 - age < 18
 - echocardiogram (reference standard)
- Exclusion criteria
 - previous cardiac surgery
 - inability to sit still for 2 min.

Interim results

- N=110 (58 with HR < 120)
- Median age 5.3 yrs (4 mo-17.6 yrs)
- Time to complete examination 3-5 min.
- Customer satisfaction: 100%
- Most common diagnoses:
 - Aortic stenosis (13), VSD (11), ASD (9)

Next steps

- Compare cardiologists' interpretation of electronically recorded sounds with Cardioscan™ interpretation
- Compare cardiologists' interpretation of recorded sounds, with and without the spectrogram + phonocardiogram

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Teaching auscultation

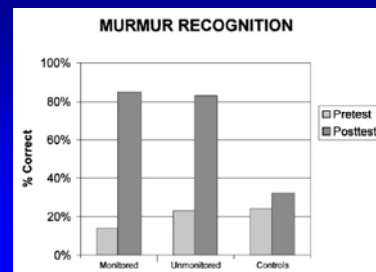
- Why should we do better?
 - Residents skills are suboptimal Pediatrics 2000;105:1184
 - Residents can be taught (they're smart)
 - They will have lots of murmurs to listen to after completing training

The Power of Repetition

- Barrett et al.
 - Drexel University, PA
 - *Objective:* does intensive repetition of 4 basic cardiac murmurs (AS, AR, MS, MR) improve proficiency in medical students?
 - 3 groups (total N=51):
 1. Listened to 500 repetitions in monitored setting
 2. Listened to 500 repetitions in unmonitored setting
 3. Control

Chest 2004;126:470-475

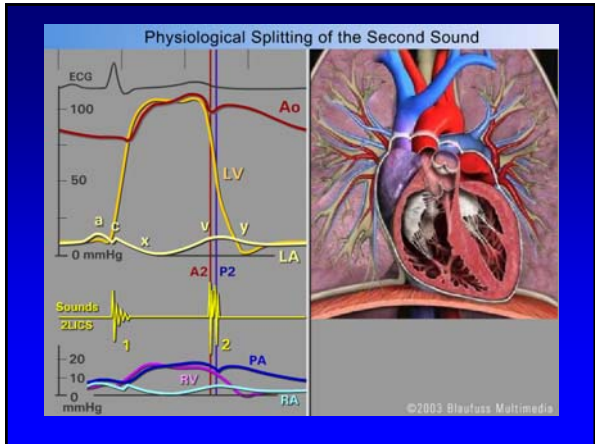
The Power of Repetition



Chest 2004;126:470-475

Educational software

- Pre- post evaluation of educational intervention using CD of heart sounds
 - improved auscultation skills in pediatric residents
Pediatrics 2004;113:1331-5
- No evaluation of phonocardiogram/spectrogram on resident learning
 - stay tuned...



Aortic Stenosis

Ejection Sound (ES):

- mobile Ao valve leaflets

Midsystolic Murmur:

- begins with ES, not S1
- ends before S2

Compare with S4-S1:

- HCM
- S4 heard at apex with bell

Aortic Regurgitation

Inspection:

- bounding (Corrigan's) pulse
- head bobbing (Musset's sign)
- compare with normal carotid

Auscultation:

- "To-fro" murmur
 - Midsystolic murmur
 - Early diastolic murmur
- 3RICS
 - "To-FRO"
- 2RICS
 - "TO-fro"

Mitral Stenosis

Listening at Base:

- abnormally loud S1 at base
- shorter S2-OS interval indicates severe MS

Listening at Apex:

- crescendo, presystolic murmur
- loud S1
- S2, OS
- mid-diastolic murmur

Inspection:

- JVP is a-wave dominant
- a-wave occurs with loud S1

Compare sounds with split S2, S3

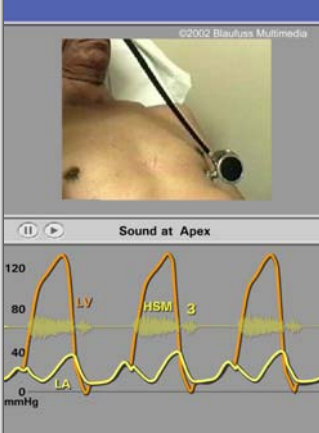
Chronic MR

Inspection:

- apex beat displaced to 7LICS
- outward excursion of stethoscope head during systole

Auscultation:

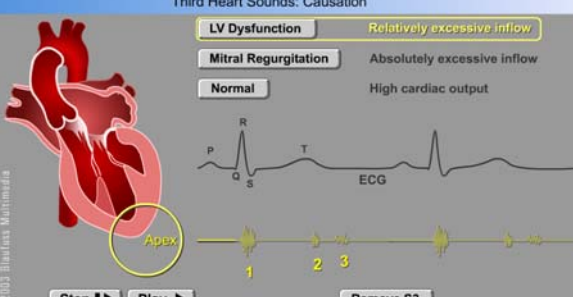
- blowing murmur with outward excursion of stethoscope
- a thudding sound with inward return of stethoscope
- murmur is holosystolic – heard best over LV
- sound is S3



Innocent murmurs

- Still's murmur
- Pulmonary flow murmur
- Cervical venous hum
- Physiologic PPS

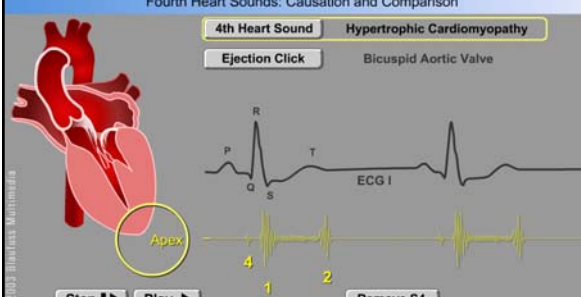
Third Heart Sounds: Causation



- LV Dysfunction**: Relatively excessive inflow
- Mitral Regurgitation**: Absolutely excessive inflow
- Normal**: High cardiac output

Step | Play | Remove S3

Fourth Heart Sounds: Causation and Comparison



- 4th Heart Sound**: Ejection Click
- Hypertrophic Cardiomyopathy**: Bicuspid Aortic Valve

Step | Play | Remove S4

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Summary

- Auscultation remains an integral and important part of clinical medicine
- CXR and ECG of little to no value prior to cardiology consultation
- Digital stethoscopes offer advantages of
 - storage and playback
 - visual display of processed acoustic signal
 - option to transmit to multiple listeners

Practice, practice, practice!

- ### Acknowledgements
- John Dyck
 - Jeffrey Smallhorn
 - Murray Robertson
 - Edythe Tham
 - Jennifer Rutledge
 - Michal Kantoch
 - Yashu Coe
 - Cecilia Lee
 - Kathryn Rankin
 - Zargis Medical, Inc.

Cost effectiveness

- Yi et al.
 - University of Cincinnati Medical Centre
 - Compared 6 strategies:

Strategy	Description
1	Physical exam ⇒ selective cardiology consult
2	Physical exam + CXR + ECG ⇒ selective cardiology consult
3	Physical exam ⇒ selective referral to echo
4	Physical exam + CXR + ECG ⇒ selective referral to echo
5	Refer all murmurs to cardiologist
6	Refer all murmurs to echo

J Pediatr 2002;141:504-511

Cost effectiveness

Strategy*	Average cost	% Pathologic murmurs detected	Incremental cost-effectiveness ratio
(1) PED>Selective to CARD	\$72	82%	—
(5) PED>Selective to ECHO	\$133	86%	Eliminated by extended dominance
(2) PED-CXR-ECG>Selective to CARD	\$137	85%	Dominated
(5) PED/All to CARD	\$174	95%	\$38,000 per additional case detected relative to strategy 1
(4) PED-CXR-ECG>Selective to ECHO	\$200	88%	Dominated
(6) PED/All to ECHO	\$332	100%	\$138,000 per additional case detected relative to strategy 5

*Strategies are ordered from lowest to highest average cost; strategy descriptions are given in text.

J Pediatr 2002;141:504-511