The Cardiovascular Examination – Is It Relevant in 2002?

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Interests: I specialize in echocardiography and serve as the Medical Director of the Cardiovascular Laboratory at Parkland Hospital. My primary interests are in applications of echocardiography, valvular heart disease, and congenital heart disease.

The following cases will be used to illustrate the role of the cardiovascular exam in the diagnosis and management of patients with suspected cardiovascular disease. The clinical history provided is deliberately minimal with the emphasis to be placed on the specifics of the physical examination. Representative heart sounds will be played utilizing a heart sound simulator and you are asked to record your impressions below.

Case 1. A 50 year old man presents with dyspnea.

His cardiovascular examination is as follows:

BP = 100/80, HR = 100, RR = 16
Jugular venous distension is present at 90 degrees, 1+ carotids
Lungs are clear
PMI is enlarged and laterally displaced
Heart sounds? Systolic Gr III/VI AS (m).

(1) CHF
(2) AS

Hepatomegaly is present with a mildly tender liver
Peripheral edema is present
Extremities are cool, diminished pulses

Case 2. A 50 year old woman presents with dyspnea.

Her cardiovascular examination is as follows:

VSD
Pulm HTN

BP = 120/70, HR = 90, RR = 18
No JVD, normal carotids
Lungs are clear
A sternal lift is present
Heart sounds? Gr IV / Systolic (m) holosyst.
Pulm Regur

No hepatomegaly
2+ distal pulses
No edema

Case 3. A 50 year old woman presents with dyspnea.

Her cardiovascular examination is as follows:

~~NAHB~~
MS

BP = 110/70, HR = 100, RR = 14
No JVD
Lungs are clear
Sternal tap is present, PMI normal
Heart sounds?
late systolic (m)

No hepatomegaly
2+ distal pulses
No edema

Case 4. A 50 year old man presents with dyspnea.

His cardiovascular examination is as follows:

~~AVM~~
Tamponade

BP = 80/50, HR = 110, RR = 20
JVP = 16cm $H2O$
Lungs are clear
PMI is not palpable
Heart sounds? intermit bruit

Palpable pulsus is present
No hepatomegaly
No edema

Osler's advice –

"Observe, record, tabulate, communicate. Use your five senses...Learn to see, learn to hear, learn to feel, learn to smell, and know that by practice alone you can become expert. Medicine is learned by the bedside and not the classroom. Let not your conceptions of disease come from words heard in the lecture room or read from the book. See, and then reason and compare and control. But see first."[1]

History of cardiac auscultation and the cardiovascular examination:

Cardiac auscultation has a long and glorious history. Hippocrates taught the art of "direct auscultation" to his students, where the physician applied his ear directly to the patient's chest in order to hear chest sounds. In 1816, Theophile Rene Hyacinthe Laennec, a French physician, found himself faced with an obese young woman with symptoms suggestive of heart disease. Direct auscultation appeared to be imprudent in this situation, so he used a piece of paper rolled into a cylinder and applied it to a patient's chest in order to hear her heart sounds. With this primitive device, he reported that he could "hear the beating of the heart more clearly than if I had applied my ear directly."[2] Laennec then designed a wooden cylinder for this purpose, which he dubbed the stethoscope (or "breast spy") and in 1821 he published a two-volume treatise of his observations with this instrument. In 1852, a New York physician, George Phillip Cammann, devised a method of attaching flexible tubing to the instrument to create a binaural instrument, creating the basic design of stethoscopes used to this day.[3] Using necropsy findings to provide clinical-pathologic correlations, physicians throughout the 19th century and the first half of the 20th century further developed and refined the cardiac examination. Many physicians applied their names to specific findings, leading to a great variety of eponyms (Graham Steell murmur, Austin Flint murmur, Corrigan's pulse, Quincke's pulse, Osler's nodes, etc...). It is curious to discover that, despite the popularity of the stethoscope, auscultation of murmurs was not considered particularly important until 1955, when Abrey Leatham proposed a system for classifying systolic murmurs.[4]

Phonocardiography was invented in 1908 and, by allowing visualization of cardiac sounds, helped to further refine cardiac auscultation. This was a flourishing technique until 1977 when financial reimbursement was discontinued, allowing this technique to fade into obscurity. [5] As other diagnostic tools became available in the 20th century, further refinements were made in the cardiac exam. Electrocardiography was introduced into clinical medicine by the early 1900's and direct written recordings of ECGs became available by the late 1940's. [6] The chest x-ray was first used to evaluate heart size in 1896[7] and became a routine diagnostic tool in cardiology. Relying on these tools (history, exam, ECG and CXR), master clinicians such as W. Proctor Harvey, Aubrey Leatham, Noble Fowler, Paul Wood, and others developed the cardiovascular examination into an art form, leading to the "golden era" of the cardiac exam by the mid-20th century. As tools for the treatment of cardiovascular disease were relatively limited at that time, cardiology in that era has been described as a "contemplative and descriptive discipline."[8]

By the 1940's, right-heart catheterization was available and left heart catheterization, including direct injection of the coronary arteries was available by the 1950's.[9] Echocardiography with real-time 2-dimensional imaging of the heart became available in the 1970's and has been identified by many authors as a major cause of decline in cardiovascular examination skills.[5, 10, 11] A wide variety of imaging techniques, including nuclear imaging, CT scanning, MRI and PET scanning are now available to further assist in cardiac diagnosis.

With the wide variety of diagnostic imaging techniques available to clinicians, some authors have questioned whether or not the cardiovascular examination has a role in the current era. In 1988, Earnest Craige mused about the role of cardiac auscultation:

> *"Should it be reserved for the occupational therapy of a dwindling coterie of antiquarians, or should it be promoted more vigorously as a viable part of our diagnostic armamentarium?"[10]*

Current status of cardiac examination skills:

Several studies have demonstrated poor cardiac examination skills in the current era, with particular emphasis on physicians in training. Mangione and Neiman evaluated the auscultatory skills of 198 residents in Internal Medicine, 255 residents in Family Practice, and 88 medical students.[12] Twelve different cardiac events were used which were recorded from patients and digitized, then played back on stethophones. The following sounds were chosen as "clinically very important" for practicing practitioners: mitral regurgitation, aortic stenosis, aortic insufficiency, combined aortic stenosis and insufficiency, mitral stenosis, patent ductus arteriosus, pericardial rub, S4, S3, opening snap of mitral stenosis, midsystolic click of mitral valve prolapse, and an early systolic ejection click. Participants were told which area of the chest was used for recording particular sounds and were given 90 seconds to listen to each recorded sound (repeated, if necessary). A non-adjusted score was calculated as the number of events identified. An adjusted score was also calculated where incorrect answers selected along with the correct answer were considered invalid. Medical students identified an average of 2.7 events out of 12 (standard deviation = 1.2), internal medicine residents identified 2.6 events out of 12 (SD = 1.4), and family practice residents identified 2.5 events out of 12 (SD = 1.4). There was no significant difference in the accuracy of these groups, identifying approximately 20% of all cardiac events on average. When scores were adjusted for incorrect answers, an average of only 10% of cardiac events were identified (adjusted score 1.1 ± 1.0 for medical students, 1.2 ± 1.1 for internal medicine residents, 0.9 ± 1.0 for family practice residents). To validate their methodology, the investigators asked a group of 10 cardiologists to complete the same testing. Accuracy rates for this group of "experienced observers" ranged between 80 and 90%.

Despite a poor performance in this testing, both groups of residents felt that cardiac auscultation was an important skill. When asked to rank the importance of cardiac auscultation, using a 1-4 scale with 1 indicating "obsolete and useless" and 4 indicating "extremely important," trainees rated the importance of auscultation as 3.8 ±

0.4. Trainees were also asked to evaluate their confidence in cardiac auscultation on a scale of 1 to 5 (1 = poor, 5 = excellent). Family practice residents rated their confidence at 2.2 ± 0.7 and internal medicine residents rated their confidence level at 2.4 ± 0.7 (P = .03). There was some correlation between the confidence score (skills self-perception) and auscultatory accuracy among internal medicine residents (r = 0.21 and P = .02 for the cumulative adjusted score) but not among family practice residents. Both groups of residents felt that more teaching of auscultation was needed, both in medical school (95% of IM residents and 100% of FP residents) and in residency training (94% of IM residents and 100% of FP residents).

Noting that only one fourth of internal medicine and family practice residencies in the United States offer formal instruction in cardiac auscultation [13], Mangione performed a similar study to address whether or not lack of proficiency in cardiac auscultation was unique to the United States. He compared the auscultatory skills of physicians-in-training from three different English-speaking countries – 189 internal medicine residents from the U.S., Canada, 89 IM residents from Canada, and 36 IM residents from the United Kingdom.[14] Using the same methodology, subjects were asked to listen to 12 cardiac events, and to complete the "attitude survey." Results were reported as the percentage of events identified out of all 12 auscultatory events. The mean identification score for U.S. residents was 22 ± 12%, for Canadian trainees was 26 ± 13%, and for U.K trainees was 20% ± 12%. A "corrected" score was also reported, where an incorrect response in addition to the correct response was scored as an incorrect answer. The mean "corrected" identification score was 10 ± 9% for U.S. trainees, 12 ± 10% for Canadian trainees, and 10 ± 9% for U.K. trainees. The Canadian scores were statistically slightly higher than the U.S. and U.K. trainees for the unadjusted scores (P = 0.02), but there was no difference between the groups for the "corrected" scores. Trainees again rated cardiac auscultation as an important skill, although Canadian residents attributed less importance than U.S. and U.K. trainees. Using the 1 to 4 scale to evaluate the relevance (1 = "obsolete and useless," 4 = "extremely important") U.S. trainees rated the importance of auscultation as 3.8 ± 0.4, U.K. trainees as 3.7 ± 0.5, and Canadian trainees as 3.4 ± 0.6.

This type of performance in the cardiac exam prompted one physician (Dr. Henry Schneiderman) to declare that the "end-stage failure of physical examination skills has arrived."[15] Dr. Schneiderman describes "the current situation" in cardiac auscultation as follows:

> *"The intern lurches from bed to bed on a bad admitting night, listening briefly by rote, comprehending little to nothing, copying the plausible 'grade 2/6 SEM" from the equally undependable physical examination of the assistant resident, gaping in terror that he will err and harm a patient before the echocardiogram comes, like the cavalry, to the rescue."[15]*

It is important to acknowledge that inaccuracy in physical examination skills is not limited to trainees. In the studies by Mangione, the small group of cardiologists used to validate the testing approach achieved an accuracy of 80-90%, substantially better than the students and residents but still with some inaccuracy[12]. Jost, et al evaluated the diagnostic accuracy of the cardiac exam by cardiologists in a series of patients with systolic murmurs who were referred for echocardiography.[16] This study consisted of

100 consecutive adults who were referred for echocardiography for evaluation of a systolic murmur. Prior to their echocardiogram, they were evaluated by one of eight physicians (4 cardiology staff and 4 cardiology fellows). The cardiac exam included assessment of jugular venous pressure, assessment of the apical impulse and carotid impulse, and cardiac auscultation at rest and with the Valsalva maneuver. By echocardiography, 21 patients had no abnormal findings on echo and these patients were classified as having a "functional" or innocent murmur. The sensitivity of the cardiac exam for diagnosing a functional murmur was 61% with a specificity of 91% and overall accuracy of 83%. Of the remaining 79 patients with evidence of organic heart disease, 29 patients were categorized as having "significant" heart disease (defined as moderate or severe valvular disease, congenital shunts, or intraventricular gradients). For patients with "significant heart disease," the sensitivity of the cardiac exam was 79% with a specificity of 93% and overall accuracy of 75%. For aortic stenosis, the sensitivity of the cardiac exam was 71%, specificity 83%, with overall accuracy of 80%. For the diagnosis of mitral regurgitation, sensitivity, specificity and accuracy of the cardiac exam were all 70%. For combined valvular disease (aortic and mitral lesions), the sensitivity was lower (55%) while specificity remained good (88%) and overall accuracy was 81%. Thus, while the cardiac exam by cardiologists performed reasonably well overall, significant limitations were observed and several important cardiac diagnoses were missed by the cardiac exam alone. These missed diagnoses included: aortic stenosis in 4 patients (3 with LV dysfunction), hypertrophic obstructive cardiomyopathy in 2 patients (misdiagnosed as aortic stenosis in 1), and severe aortic regurgitation in 1 patient.

In a pediatric study, the auscultatory skills of pediatric cardiologists was assessed in patients with a murmur who were referred for echocardiography.[17] Patients were examined by one of 8 pediatric cardiologists (ranging from 1-20 years experience) immediately prior to their echocardiogram. Aortic valve disease was found in 123 patients and was the suspected primary diagnosis based on the cardiac exam in 62 for a sensitivity of 50%. When the diagnosis of "possible" aortic valve disease was also included, the sensitivity of the cardiac exam for diagnosing aortic valve disease increased to 72%. Aortic valve disease was "missed" by the clinical exam in 35 patients - in some cases, another cardiac diagnosis was accurately made while in other cases a completely erroneous diagnosis was made (e.g. pulmonic stenosis, innocent murmur, VSD, etc...). The cardiac exam performed well in excluding the diagnosis of aortic valve disease with a negative cardiac exam predicting the absence of disease with 91% specificity. The cardiac exam was less sensitive for the diagnosis of subaortic stenosis, with a sensitivity of only 31% although specificity remained high at 97%. Mitral valve disease was found in 34 patients and was diagnosed as present or at least possible in 18/34 for an overall sensitivity of 53%. Specificity for excluding mitral valve disease was excellent at 99%.

Lok, et al, studied the interobserver agreement on the presence or absence of gallop sounds.[18] In this study, 40 patients with heart disease and 6 patients without heart disease were studied. Two cardiologists, one general internist, three residents (PGY 2,3 and 4) and 2 interns (PGY 1) performed cardiac auscultation on each patient. A phonocardiogram was obtained on each patient within a few minutes to 2 hours from the time of the physical exam and served as the "gold standard." Overall, the positive predictive value of the cardiac exam for detecting an S4 was 51% with a negative predictive value of 82%. For an S3, the positive predictive value was 48% with a negative predictive value of 77%. Interobserver variability was poor, as described by the calculated kappa coefficient. Used as a measure of interobserver agreement beyond that expected by change, a kappa coefficient $< .20$ indicates poor agreement, between 0.21-.60 indicates fair-moderate agreement, and a coefficient > 0.61 up to 1.00 indicates good to excellent agreement. In this study, the kappa coefficient for interobserver agreement on the presence of an S4 was 0.05 and for the presence of an S3 was 0.18 indicating very poor interobserver agreement. It should be noted that the presence of an S4 on phonocardiogram does not necessarily correlate with an audible cardiac sound since the S4 is a very low frequency sound which can be difficult to hear. However, the poor interobserver variability remains an impressive finding of this study.

Thus, in the hands of either adult or pediatric cardiologists, the cardiac examination performs reasonably well. Unfortunately, there is essentially no data assessing the performance of the cardiac examination by non-cardiologist physicians and poor interobserver agreement on exam findings is also problematic.

Thus, the inadequacy of auscultatory skills of physicians has been well documented, presumably representing a decline from previous skill levels. A variety of potential causes have been postulated. A lack of emphasis on teaching the cardiac examination in both medical school and residency training has been decried by several authors.[5, 10, 11, 15, 19, 20] A lack of emphasis on bedside rounds as a method of teaching is also considered to play a significant role. Some physicians may consider physical diagnosis to be "too subjective" to have significant value. Many authors suggest that the easy availability (and perhaps more objective data) available from other technologies (in particular, echocardiography) has led physicians to increasingly rely on imaging techniques rather than their own physical examination skills.[5]

Is the cardiac examination still considered relevant?

Despite the documented decline in physical examination skills, physical diagnosis skills are still considered to be integral part of medical education. Physical diagnosis skills are considered part of the "core competency" for medical student education as identified by medical educators.[21, 22] As per the Association of American Medical Colleges Learning Objectives for Medical Student Education, students are expected to demonstrate the ability to perform both complete and organ specific physical examinations.[23] In the near future, students will be asked to complete objective structured clinical examinations (OSCEs) as part of the National Board of Medical Examiners Step II examination.

Status of cardiac examination at UT Southwestern:

At UT Southwestern, 2nd year medical students receive instruction in the cardiac examination as part of their Clinical Medicine: Principles and Practice course. An initial 2 hour lecture is given on the cardiac history, cardiac exam and auscultation. A heart sound simulator is used to assist in the teaching of cardiac auscultation. In addition, the cardiac examination is also emphasized (and demonstrated using the heart sound simulator) during lecture sessions on valvular heart disease, congenital heart disease, myocardial and pericardial diseases. The heart sound simulator is available in the library for student self-study and 5-6 questions using the heart sound simulator are included on the final course examination.[24] During the 2nd year, students also make weekly rounds with internal medicine residents to receive some initial "hands-on" exposure to patients, performing histories, physical examinations, and documentation ("H & P write-ups"). For 3rd and 4th year students on their clinical clerkships and for medicine residents in training, there is no formal training in cardiac examination and auscultation but, rather, training depends on the clinical faculty.

At UT Southwestern, the cardiac examination (as described in the physical diagnosis guidelines for medical students) includes the following:

- Record HR, BP, and RR
- Observe JVP
- Palpate arterial pulses – carotid, radial, brachial, femoral, popliteal, DP, PT
- Precordial palpation, assess PMI
- On cardiac auscultation, identify timing of events, use listening areas and positioning of the patient, describe murmurs, including radiation and effects of inspiration.

Federal guidelines for documentation of a comprehensive cardiac examination are more extensive (see appendix A).

To evaluate the status of the cardiovascular examination at UT Southwestern, I reviewed the charts of 43 consecutive patients admitted to Internal Medicine services in the last month with a primary cardiac diagnosis who were referred for an echocardiogram. As the purpose of this study was to evaluate the documentation of the cardiac examination, not its accuracy, echocardiographic results were not evaluated. Documentation of the cardiac examination as recorded in the admission progress notes or cardiology consult notes was recorded, including the type of examiner and presence or absence of documentation of specific elements of the cardiac exam. A total of 86 physical examinations were documented in the medical record for these patients. Physical examination were recorded by non-cardiology attending (n = 21), cardiologist (attending or fellow, n = 14), residents (n = 43), or medical students (n = 8)). Admission diagnoses included CHF (n = 12), chest pain or acute coronary syndrome (n = 14), syncope (n = 7), arrhythmia (n = 5), endocarditis (n = 2), prosthetic valve dysfunction (n = 2), and pericarditis (n = 1). Examination elements were categorized as recorded or not recorded. If a murmur was documented, elements further characterizing the murmur (grade, location, character, and radiation) were categorized as recorded or not recorded. The most common cardiac examination documented was "RRR s m/r/g."

Exam finding:	*all examiners*	*faculty*	*cardiologist*	*residents*	*students*
Heart rate	83%	53%	93%	93%	100%
Regularity	71%	57%	86%	70%	88%
Blood pressure	86%	53%	100%	95%	100%
Respiratory rate	76%	43%	71%	88%	100%
Evaluation of JVP	59%	33%	93%	63%	50%
Carotid impulse	6%	0%	7%	14%	13%
Lung exam	95%	81%	100%	100%	100%
PMI, palpation	7%	15%	7%	2%	13%
S1 and S2	30%	5%	71%	35%	0%
S3 and S4	52%	43%	71%	47%	75%
Murmur	77%	71%	57%	91%	50%
Liver/spleen	12%	14%	7%	12%	13%
Distal pulses	26%	5%	7%	37%	50%
Edema	92%	76%	100%	95%	25%

Documentation of cardiac murmurs by the entire group is shown below:

Murmur	***present***	***not present***		***not documented***	
	33%	44%		23%	
Characterization of murmur if present:					
	All examiners	faculty	cardiologist	residents	students
Description	24%	100%	80%	57%	--
Location	63%	75%	40%	64%	--
Radiation	22%	25%	0%	29%	
Grade	81%	100%	80%	71%	

Supervising attending faculty are required to review the history and exam as documented by the residents under their supervision and are required to verify or amplify the physical exam findings without being required to repeat documentation already performed by the resident. Therefore, it is not surprising that documentation of cardiac exam findings was lowest in the attending faculty group. Overall, medical student documentation was no more complete than that of medical residents. Of significance, jugular venous pressure was documented in 59% of patients overall and was documented in 66% of patients with a diagnosis of CHF. Documentation of the carotid impulse was rarely found. Cardiac palpation was rarely documented, seen in only 7% overall. The most common documentation of the cardiac exam was "RRR without m/r/g." S1 and S2 were rarely specifically documented. Gallop sounds were more frequently documented due to the frequent use of "RRR without m/r/g" for the cardiac exam. The presence or absence of an S3 was documented in 59% of patients with a diagnosis of CHF. Murmurs were described as present in 33%, were documented as absent in 44% and were not documented at all in 23%. No student heard a murmur. When a murmur was documented, grade was nearly always documented (81%) but further description was uncommon. Noncardiology faculty documented the most complete characterization of murmurs. No examiner commented on respiratory variation of murmurs or the response to maneuvers (i.e. dynamic auscultation). Liver size was infrequently documented (12%), even in patients with congestive heart failure (24%). Peripheral pulses were documented in 26%, but documentation of specific pulses was documented in only 1 exam. The presence or absence of peripheral edema was documented in nearly all patients (92%)

Because of the small number of subjects in this survey, it is not possible to make statistically significant comparisons between groups of examiners. However, this small survey demonstrates that in our clinical practice, documentation of the cardiac examination is frequently incomplete. It is possible that more complete examinations are performed but not documented. Key elements of the cardiovascular examination were frequently not documented in this population of patients admitted with a primary cardiac diagnosis and, therefore, a high probability of cardiac disease.

Does the cardiac exam provide useful prognostic information?

Perhaps the lack of skill and lack of documentation of the cardiac examination reflect uncertainty about the utility of cardiac examination findings. The relevance of physical examination and clinical evaluation has been addressed in the "Rational Clinical Examination" series in the Journal of the American Medical Association. Cardiac exam topics which have been discussed in this series include evaluation of systolic murmurs[25], evaluation of central venous pressure[26], evaluation of possible myocardial infarction[27], evaluation of clubbing[28], evaluation of aortic regurgitation[29], and the evaluation of left-sided heart failure[30]

Badgett, et al reviewed the literature to determine the utility of the clinical examination in the diagnosis of left-sided heart failure and made several conclusions.[30] There is only limited data regarding the utility of the clinical examination in assessing increased left ventricular filling pressure. The presence of radiographic redistribution of pulmonary vascular markings and jugular venous distention have both been shown to be very useful markers of increased LV filling pressures, whereas the presence of dyspnea, orthopnea, tachycardia, rales, abdominal-jugular reflux, and cardiomegaly on chest x-ray are less consistently helpful. The presence of peripheral edema is only helpful when present, its absence does not help predict LV filling pressures. In patients who are known to have systolic dysfunction, the finding of any of these abnormalities suggests increased filling pressures, whereas in patients whose systolic function is unknown, a single abnormal finding has less predictive value.

Badgett, et al found that 5 clinical findings were very helpful in identifying patients with a reduced ejection fraction (less than 40%). These include cardiomegaly on chest x-ray, radiographic redistribution, anterior q-waves on ECG, left bundle branch block, and an abnormal apical impulse. The presence of anterior q-waves or LBBB had the strongest predictive value (specificity of > 90%). Using these predictors, patients can be stratified into low, intermediate or high-probability of having systolic dysfunction. Patients with no abnormal findings have a low probability of systolic dysfunction while patients with ≥3 findings have a high-probability of systolic dysfunction.

In patients with valvular heart disease, in addition to identifying the valve lesion, the physical exam may also help to predict filling pressures and identify patients with LV systolic dysfunction. In the VA Cooperative Study on Valvular Heart Disease, clinical implications of third heart sounds was assessed in 1281 patients undergoing cardiac catheterization for evaluation of aortic and/or mitral valve disease.[31] Physical examinations by referring cardiologists were documented immediately before catheterization. An S3 was more commonly found in patients with mitral valve disease than with aortic valve disease. A low ejection fraction was strongly associated with the presence of an S3 in those patients with aortic stenosis and mixed aortic valve disease (mixed stenosis/regurgitation), but not in patients with aortic regurgitation or mitral valve disease. The presence of an S3 was predictive of elevated pulmonary capillary wedge pressure or left atrial pressure in patients with aortic stenosis, mixed aortic valve disease, and mixed mitral valve disease but not in patients with pure aortic regurgitation, pure mitral stenosis, or pure mitral regurgitation.

Drazner, et al described the prognostic importance of elevated jugular pressure and a third heart sound in patients with heart failure and known systolic dysfunction.[32] In this patient population, elevated jugular venous pressure and the presence of an S3 were commonly seen in patients with more advanced heart failure as demonstrated by higher New York Heart Association Class, lower ejection fraction, and higher resting heart rate. The presence of elevated jugular venous pressure and an S3 were both predictive of increased risks of adverse outcomes (see tables). Thus, in heart failure patients with known systolic dysfunction, the cardiac exam has importance clinical and prognostic implications.

Prognostic importance of elevated JVP in patients with CHF

	Elevated JVP	
	Present	absent
	(event rate per 100 person-yrs)	
death (all cause)	20.3	13.3
hospitalization for CHF	23.8	13.0
death or hospitalization	38.1	22.0
death from pump failure	12.4	6.3

Prognostic importance of S3 in patients with CHF

	S3	
	Present	absent
	(event rate per 100 person-yrs)	
death (all cause)	17.5	13.0
hospitalization for CHF	20.9	12.1
death or hospitalization	30.9	21.4
death from pump failure	10.4	5.9

How do we improve performance and accuracy of the cardiovascular examination?

Several studies have looked at different methods of teaching the cardiovascular examination to medical students with varying results. Mangione, et al assessed the utility of computer-assisted instruction in teaching cardiac auscultation to medical students at the Medical College of Pennsylvania.[33] All 2nd year students received 2 hours of lectures, including the use of audiotapes and stethophones. During the 3rd year, students were randomized to 3 hours of seminar teaching on the cardiac exam with the use of audiotapes (group 1), the use of a computer based program for learning auscultation (group 2), or both (group 3). Pre-and post tests of identification of heart sounds were given at the beginning and end of the 3rd year. No significant difference in performance was seen between the pre- and post-test results in any of the study groups. The authors concluded that computer-based learning was at least as effective as small group seminars for teaching auscultation. In this study, pre-test scores average approximately 60% for identifying heart sounds which is somewhat surprising.

In a later study, Mangione et al again evaluated the efficacy of small group teaching of auscultation to 3rd year medical students during their internal medicine clerkships. Forty-five students met weekly for 1 hour for 3 weeks with a faculty member who reviewed cardiac auscultation, using prerecorded heart sounds and stethophones. A control group of 21 students had no specific training in auscultation. Students completed an objective structured clinical examination (OSCE) at the end of their 3rd year, using 4 cardiac events (S3, pericardial rub, mid-systolic click, aortic regurgitation murmur) played over stethophones. Students who had participated in the small group teaching sessions performed much better in identifying heart sounds than those students who had not participated.

	S3	pericardial rub	AI murmur
Small group teaching	69%	49%	29%
No small group teaching	29%	33%	14%

Stern, et al evaluated the use of a multimedia tool to improve cardiac auscultation skills among 3rd year medical students at the University of Michigan.[34] All students had traditional ward/clinic rotations during their medicine clerkship. Seventy-three students (cohort A) also completed 3 hours of CD-ROM based comprehensive cardiac cases (which included synthesized heart sounds, phonocardiograms, xrays, ECGs, and echocardiograms) as well as completing 20 short cardiac examination cases on CD-ROM (requiring approximately 2 hours to complete). Thirty-nine students (cohort B) completed the short cardiac exam cases on CD-ROM but not the comprehensive cardiac cases. Thirty-nine control subjects (cohort C) had no CD-ROM training. Prior to the study and at the end of the 3rd year, students were asked to complete a 10-item test of auscultation (listening and identifying heart sounds). For reference, "expert cardiologists" demonstrated 77% accuracy in identifying heart sounds. At baseline, 3rd year students in this study identified about 47% of heart sounds with no difference between the cohort groups. All students improved from baseline at the repeat testing but students in cohort A had the greatest increase in performance (identified 71.1% of heart sounds) as compared to cohort B (69.0%) and students in cohort C (60.3%).

These studies indicate that any attention paid to the cardiac exam will likely result in some improvement in exam skills for medical students. Bedside teaching, use of audiotapes, heart sound simulators and stethophones, or CD-ROM programs designed to teach auscultation all have some effectiveness in improving cardiac exam skills.

Is the cardiac exam cost effective?

The cardiac examination may have relevance in terms of cost control. Considered a routine part of patient evaluation, it costs nothing but its documentation is required in order to bill for evaluation and management services. In comparison, an electrocardiogram costs approximately $125, a chest x-ray costs approximately $150, a cardiac consultation costs approximately $175, and an echocardiogram costs approximately $1200. The ACC/AHA Consensus conference on Echocardiography states that "echocardiography should not be used to replace the cardiovascular examination" but, rather, should be used "in patient(s) with cardiorespiratory symptoms as well as in asymptomatic patient(s) if clinical features indicated at least a moderate probability ... (of) ...... structural heart disease."[35]

Bedside ultrasound, will it replace the cardiac exam?

Clearly, in its current form, echocardiography is not a cost effect replacement for the cardiac exam. However, with continuing improvements and advances in technology, portable ultrasound units are now commercially available which may allow echo images to be incorporated in the bedside exam in the future. Manufacturers of these units have touted their utility in bedside diagnosis but little objective data is available.

Several small studies have evaluated the utility of using standard echocardiography instruments to perform rapid, bedside clinical diagnoses. Hu, et al compared a limited (10 minute) echocardiogram performed by cardiology fellows in training versus the cardiac examination as performed by a similar group cardiology fellows.[36] All trainees had equivalent levels of training (were "board eligible internists" currently in cardiology fellowship with less than 2 months of formal full-time echo training). A complete echocardiographic study performed by trained sonographers and interpreted by full time echocardiographers was used as the gold standard for comparison. Compared to the physical exam, the limited echo was superior in assessing LV systolic function, including the detection of systolic dysfunction and regional wall motion abnormalities. The presence of aortic and mitral valve disease was detected equally by physical exam and limited echo study, but more accurate information was gained from the limited echo study. When compared to the full echo study, diagnostic accuracy of the brief echo study was significantly decreased. Thus, in the hands of cardiology fellows in training, the limited echo examination appears to have some utility.

Kimura, et al. evaluated the utility of limited echo exams performed in the emergency room setting.[37] In 124 patients presenting to the emergency room with symptoms suggestive of cardiac disease, screening cardiac exams (limited to the parasternal long-axis view, with and without color Doppler) were obtained by either a trained cardiac sonographer or a cardiologist. Findings from the limited echo exam were compared with the clinical evaluation (history, exam, ECG, and chest x-ray) as performed by the emergency department physician. Thirty-two percent of subjects had an abnormal screening examination and 2 cases required "unblinding" of the study (1 aortic dissection, 1 tamponade). "Full echocardiograms" were obtained on 36 patients and served as the "gold standard." Among patients with a normal "full" echocardiogram, the clinical evaluation was normal in most (n = 13), abnormal in 3. The screening echocardiogram in these patients was normal in 15, abnormal in 2. Among patients with an abnormal "full" echocardiogram, the clinical evaluation was abnormal in 2/3 (abnormal in 13, normal in 6) while the screening echo was abnormal in most (abnormal in 16, normal in 3). Thus, the clinical examination and the screening ultrasound exam were not significantly discrepant from one another in classifying patients as normal or abnormal. The screening echo exam correctly diagnosed 22/30 (73%) of the abnormal findings found on the full echo evaluation as compared with the clinical evaluation, which detected on 7 of 30 abnormalities (23%). The major advantage of the screening echo exam in this small study was better detection of LV systolic dysfunction and more accuracy in diagnosis of valvular lesions. In a small substudy, 2 nurses, one paramedic, and one cardiovascular technician were "trained" to perform limited echo studies. Training consisted of a brief lecture, followed by 20 "proctored" hands-on sessions of no more than 10 minutes. For those patients whose screening study was performed by a one of these personnel, the quality of the echo data was graded as substantially worse with an average "quality score" below adequate. Despite the poor image quality, the diagnostic results were similar to those seen in the main study.

Vourvouri, et al reported their experience using a hand-held ultrasound unit to perform bedside echocardiography in an outpatient setting.[38] One hundred and fourteen unselected patients presenting to an outpatient cardiology clinic were studied with 2 consecutive cardiac exams – a standard "full" echocardiogram and a limited echo study (less than 5 minutes) performed with the SonoHeart instrument. Studies were performed by a single physician specifically trained in echocardiography. LV and RV global function and internal cavity dimensions were compared between the two instruments with good agreement between imaging techniques (93% for global LV function and 99% for global RV function). Other abnormalities such as valvular disease, pericardial disease and congenital heart disease were also identified by the SonoHeart exam but usually required a standard echocardiographic study for full analysis. The authors conclude that the bedside unit can be used as a screening tool and in setting where a rapid diagnosis is essential.

As these studies indicate, bedside echocardiography may play a role currently or in the future to enhance the bedside evaluation of patients with suspected cardiac disease. However, some significant limitations need to be addressed. Current portable machines have limited diagnostic capabilities compared to standard echo machines although this will become less significant in the future. Appropriate utilization of these units requires a knowledgeable and trained user. Currently, the American Society of Echocardiography recommends that persons using handheld ultrasound units for limited, focused bedside examinations have at least level I training in echocardiography (3 months of training in echocardiography with 75 full transthoracic studies performed and 150 studies interpreted with supervision) and strongly encourages level II training (an additional 3 months with 75 additional transthoracic studies performed and an additional 150 studies interpreted).[39] Level II training is required in order to independently interpret echocardiograms. Currently training is undertaken as part of fellowship training in cardiovascular disease. Will there be a role for echo training as a part of Internal Medicine training if limited bedside ultrasound exams became routine?

Current hand-held units have only limited capability to archive images for later interpretation. If stored images cannot be reviewed easily, reporting of results lies in the hands of the operator who may be limited in skill. Without full archive capability, formal interpretation and reporting (and thus, billing) are not possible. Limited bedside echo exams should not replace a full echocardiographic study when a complete evaluation is warranted. The above studies have shown that, while bedside echo studies performed by trained sonographers or cardiologists have good accuracy, full characterization of cardiac disease requires a complete study. It can be anticipated that billing for a limited echo study followed by full echocardiographic study will be problematic.

Why can't we hear? Are electronic stethoscopes the answer?

While the audible range of sounds for humans is 30-18,000 Hz, the optimal frequency range is between 1000-2000 Hz. Most cardiac sounds are < 150 Hz. In addition, conditions for auscultation are often sub optimal. Optimal background noise for good auscultation is <35dB but typical noise levels in exam rooms are 60-75dB and are substantially higher in other settings (emergency room, intensive care units, etc.)

Electronic stethoscopes represent another technologic advance with a potential to improve skills in cardiac diagnosis. All electronic stethoscopes amplify heart sounds, potentially rendering them more easily appreciated. Most current models amplify all sounds equally, although some models allow for some selective amplification of low frequency sounds versus high frequency sounds by offering a bell (low frequency) and a diaphragm mode (high frequency). Electronic stethoscopes tend to attenuate higher frequency sounds, making them potentially less audible than with a traditional acoustic stethoscope. While amplifying heart sounds, they also amplify noises made by stethoscope manipulation as well as amplifying other electronic and ambient noises. Some models offer an option to export heart sound information for display (i.e. a phonocardiogram), although the technique for manipulating recorded heart sounds is currently quite cumbersome. While phonocardiography is no longer used as a routine clinical tool, the ability of electronic stethoscopes to record heart sounds and provide a written record of auscultatory findings may result in a resurrection of this technology.

Currently, electronic stethoscopes have a limited role. Grenier, et al, compared a series of 3 electronic and 3 acoustic stethoscopes.[40] Nine cardiologists, 10 general practitioners, and 11 nurses performed 378 comparative evaluations. For each comparative evaluation, the examiner performed 3 successive auscultations of a patient using 3 different stethoscopes, recording their observations. Evaluation included the ability to appreciate cardiac sounds (S1, S2, S3, and S4, clicks and murmurs), appreciation of carotid bruits, and Korotkoff sounds. The crispness of sound, background noise, comfort and overall appreciation were also evaluated. Acoustic stethoscope were deemed superior in 71% percent of cases, both in terms of detecting heart sounds, and overall comfort and ease of use. Since electronic stethoscopes are more expensive than traditional acoustic stethoscopes and have more potential for malfunction, they are in limited use currently. In the future, the use of electronic stethoscopes to provide a phonocardiographic record of heart sounds is quite attractive.

Is the cardiac exam relevant in 2002?

The cardiac examination is considered a required element of clinical evaluation by medical educators, the federal government, and private party insurers. As such, it needs to be performed and documented. At no cost, it helps to provide a clinical diagnosis or at least suggest the presence of cardiovascular disease requiring further evaluation. In addition, there are some prognostic implications to physical exam findings, as discussed earlier. Thus, the cardiac examination can be a useful tool in making treatment decisions, especially in the initial evaluation of patient before more advanced diagnostic testing is available. As a screening tool, the cardiac exam can help to guide the appropriate utilization of other, more expensive technology such as echocardiography.

However, adequate performance of the cardiac examination requires training and practice and it appears that the level of training currently achieved by medical students and physicians in training is not adequate to assure competency. Additional training should be integrated throughout the curriculum but will require a time commitment from both trainees and educators. "Testing what we teach" would give further emphasis to the importance of physical diagnosis skills. Written exam questions regarding the physical examination are routinely included in board certification examination but do not test the physician's ability to adequately perform the exam. Finally, newer technologies such as electronic stethoscopes with phonocardiographic recording and bedside ultrasound may help to supplement the cardiac exam and improve its accuracy, or may ultimately result in the demise of the cardiac exam.

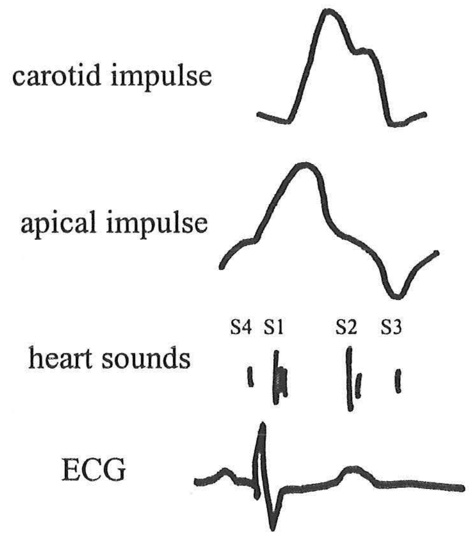
Appendix A. Guidelines for a comprehensive cardiovascular examination as defined by the Center for Medicare and Medicaid Services (formerly the Health Care Financing Administration).[41] As per their guidelines, a comprehensive cardiovascular examination includes the following:

-	**Measurement of any 3 of the following 7 vital signs (may be measured and recorded by ancillary staff) – 1) sitting or standing blood pressure, 2) supine blood pressure, 3) pulse rate and regularity, 4) respiration, 5) temperature, 6) height, 7) weight.**
-	**General appearance of the patient (e.g. development, nutrition, body habitus, deformities, attention to grooming)**
-	**Inspection of conjunctivae and/or lids**
-	**Inspection of teeth, gums and palate**
-	**Inspection of oral mucosa (pallor or cyanosis)**
-	**Examination of neck veins**
-	**Examination of thyroid**
-	**Assessment of respiratory effort**
-	**Auscultation of lungs ("Lungs clear" is inadequate documentation)**
-	**Palpation of heart (describe PMI – location, size, forcefulness; thrills, lifts, palpable S3 or S4)**
-	**Auscultation of the heart, including normal and abnormal sounds, murmurs**
-	**Measurement of BP in two or more extremities when indicated (e.g. dissection, coarctation)**
-	**Examination of carotids (waveform, amplitude, bruits, etc.)**
-	**Examination of abdominal aorta**
-	**Examination of femoral pulses (amplitude, bruits)**
-	**Examination of pedal pulses**
-	**Evaluation of extremities for edema and/or varicosities**
-	**Examination of abdomen, evaluate for masses or tenderness**
-	**Examination of liver, spleen**
-	**Stool sample for occult blood if anticoagulation or lytic therapy considered**
-	**Inspection of skin**
-	**Mental status evaluation for orientation to time, person, place, evaluation of mood and affect**
-	**Examination of back (kyphosis or scoliosis)**
-	**Examination of gait**
-	**Assessment of muscle strength and tone**
-	**Inspection and palpation of digits and nails**

Appendix B.

CARDIAC EXAM PEARLS (adapted in part from reference 42):

1. **At the start of auscultation, first identify systole and diastole.** Use either the carotid pulse or the apical impulse for timing. S1 occurs immediately before the carotid or apical impulse while S2 occurs shortly afterwards. It is usually easiest to identify systole and diastole when auscultating at the base of the heart.



2. "Inching" – start where systole and diastole are clearly identified, then move slowly to other precordial locations.

3. **Listen to heart sounds (S1 and S2) first!**
    a. S1 is soft if there is a long PR interval, depressed LV contractility, a flail mitral leaflet, LBBB, or premature closure of the aortic valve in acute AR
    b. S1 is increased in intensity with a short PR interval, vigorous LV contractility, some cases of mitral valve prolapse, left atrial myxoma, and mitral stenosis with a pliable valve
    c. S2 is one of the most valuable parts of the cardiac exam – listen to both components – A2 and P2, inspiration produces audible splitting
    d. P2 is normally softer than A2 (is inaudible in as many as 50% of adults over age 60). P2 is almost never heard at the apex. If splitting of S2 is audible at the apex, consider pulmonary hypertension.
    e. Fixed splitting of S2 is heard in <u>most</u> patients with ASD. Causes of wide (but not fixed) splitting of S2 include RBBB, massive pulmonary embolism with RV failure, pulmonary hypertension with RV failure, PS
    f. To differentiate fixed splitting of S2 from wide splitting, have patient stand – fixed splitting persists, wide splitting will decrease
    g. Paradoxical splitting of S2 (maximally splitting in expiration, narrows in inspiration) is caused by delayed aortic valve closure – heard in LBBB, LV outflow tract obstruction, and severe LV dysfunction.

4. **Use selective listening** – listen to heart sounds first, then listen to systole, then diastole. Concentrate on characterizing each sound individually.

5. **S3** is a normal finding in children and young adults, also heard in causes of ventricular volume overload. Common in heart failure, has prognostic significance. S3 is a low frequency sound, often heard only with the bell applied lightly. S3 is heard best at the apical impulse, in the left lateral decubitus position (often inaudible when supine). Try the following mnemonic:

   "slosh- ing in"
   S1 S2 S3

6. An audible **S4** is always considered abnormal and is often palpable at the apex. Exam is done with the bell (light pressure) in the lateral decubitus position. To differentiate from splitting of S1, apply pressure to the bell (functionally making it a diaphragm, filters out low frequency sounds). If the sound disappears, it is a split S1. Try the following mnemonic for S4:

   "a-STIFF heart"
   S4 S1 S2

7. For patients with **emphysema**, heart sounds may be best heard in the subxiphoid region or at the LLSB.

8. Other sounds in systole – clicks
   a. Early systolic clicks occur shortly after S1 (say "pa-da" quickly) – caused by bicuspid aortic valve, pulmonic stenosis, or dilated great artery (aortic aneurysm, idiopathic dilatation of pulmonary artery)
   b. Mid-systolic clicks – heard in mitral valve prolapse (timing moves with changes in LV volume), also heard with ventricular or atrial septal aneurysms, mobile atrial or ventricular tumors, LV free wall aneurysms.

9. Other sounds in diastole – opening snap of mitral stenosis, tumor plop (atrial myoxoma), pericardial knock of constrictive pericarditis.

10. *"Heart murmurs with no intrinsic cardiac abnormality are far more common than those with organic cardiovascular disease. Therefore, ruling out significant heart disease is an important aspect of everyday clinical practice." [42]*

11. **STEP 1 IN EVALUATION OF MURMURS – IS IT SYSTOLIC, DIASTOLIC, OR CONTINUOUS?**

12. **STEP 2 – CHARACTERIZE THE MURMUR – DURATION, SHAPE AND TIMING, GRADE, FREQUENCY (high or low frequency), LOCATION AND RADIATION.**

13. Types of murmur (character):

a. Systolic

  i. Ejection murmurs – starts after S1, crescendo-decrescendo

    Causes: flow murmurs (normal valves), abnormal semilunar valves, ejection into a dilated great vessel

  ii. Holosystolic murmurs – starts with S1, constant amplitude throughout systole

    Causes: MR, TR, VSD

b. Diastolic (always pathologic)

  i. Decrescendo – typically high frequency, caused by semilunar valve regurgitation

  ii. Low pitched, rumbling murmur – across AV valve – either AV valve stenosis (MS, TS) or increased flow across an AV valve

c. Continuous murmur – begin in systole, peak in mid-late systole, "spill-over" into diastole

14. Grading of murmurs:[42]

a. Grade 1 . The faintest murmur that can be heard under optimal conditions.
b. Grade 2. A soft but readily audible murmur.
c. Grade 3. A prominent murmur and should always stimulate a careful search for cardiac disease.
d. Grade 4. A very loud murmur that is palpable (thrill present).
e. Grade 5. Louder still (thrill).
f. Grade 6. Murmur audible with stethoscope held off the chest wall (thrill).

15. Features that suggest an organic murmur (underlying heart disease):

a. all diastolic murmurs
b. all pansystolic or late systolic murmurs
c. all continuous murmurs
d. very loud murmurs, grade 4 or greater

16. Features associated with a murmur that suggest a cardiovascular abnormality:

a. an ejection click
b. audible splitting of S2 in expiration, fixed splitting of S2
c. opening snap
d. very loud S1
e. abnormal PMI (hyperdynamic or sustained)
f. RV heave
g. Very loud A2 or P2

17. Right-sided murmurs increase in intensity with maneuvers that increase venous return (i.e. inspiration, abdominal pressure). Left-sided murmurs increase in intensity with maneuvers that increase arterial resistance (i.e. handgrip).

18. **If listening for a change in murmur intensity (with maneuver), listen at the edge of the murmur's radiation where changes in intensity are easier to detect.**

19. Palpate pulses – use carotid pulse as a marker of LV stroke volume and ejection velocity, also reflects compliance of carotid. **Use distal pulses to detect subtle abnormalities such as pulsus alternans, pulsus paradoxus.**

20. **Pulsus paradoxus – exaggerated inspiratory fall in SBP (> 10-12mmHg) . This is palpable!!! Peripheral arterial pulses decrease or disappear in inspiration. Use BP cuff to quantitate magnitude. Causes include – TAMPONADE, also asthma and emphysema, morbid obesity, severe CHF.**

21. **Calculate proportional pulse pressure in patients with chronic CHF.**
    PPP = (SBP – DBP) / SBP
    Proportional pulse pressure < 0.25% correlates with a cardiac index of < 2.2l/min in this patient population.[43]

22. **Palpate the heart!** Feel for the PMI in the supine position – normal PMI has brief anterior thrust during early systole (ends before last 1/3), within 10cm of the midsternal line in the 4-5th intercostal space, small (<2-2.5cm2), only present in 1 intercostal space.
    With LV pressure overload, PMI is sustained with increased force
    With LV dilatation and volume overload, PMI is prolonged, sustained, and enlarged, usually displaced leftward and downward.

23. Palpate over sternum with firm downward pressure – sternal lift indicates wither RV overload or severe MR (systolic expansion of LA). Sustained RV lift suggests pulmonary hypertension.

24. **Evaluate jugular venous pressure**. At zero degrees, RA is 5cm below sternal angle, 2-3 cm of venous height above the sternal angle is normal. At 30 degrees of elevation or more, the RA is 10cm below the sternal angle. More than 2-3cm of visible venous waves is abnormal. Add height of venous column to 10cm H_20. **Can also evaluate neck veins in the 90 degree upright position. In this position, any visible venous waveform is abnormally elevated (add height above sternal angle to 10cmH_20.** In some patients with very high venous pressure, top of venous column may only be appreciated in the upright position. Very high JVP may cause ear lobe pulsations. Some CHF experts suggest that any clinically important JVP can be seen by examining in the 90 degree upright position, eliminating the need to evaluate the neck veins at other angles.[44]

25. Kussmaul's sign – inspiratory increase in JVP – seen in constrictive pericarditis **and severe CHF.**

References:

1. Belkin, B. and F. Neelon, *The art of observation: William Osler and the method of Zadig.* Ann Intern Med, 1992. **116**: p. 863-866.
2. Laennec, R., *A Treatise on the Diseases of the Chest.* 2nd ed. 1821, London: T and G Underwood.
3. Lyons, A. and R. Petrucelli, *Medicine: An Illustrated History.* 1978, New York: Harry Abrams.
4. Tavel, M.E., *Classification of systolic murmurs: still in search of a consensus.* Am Heart J, 1997. **134**: p. 330-336.
5. Adolph, R.J., *In defense of the stethoscope.* Chest, 1998. **114**: p. 1235-1236.
6. Fisch, C., *Evolution of the electrocardiogram*, in *An Era in Cardiovascular Medicine*, S.B. Knoebel and S. Dack, Editors. 1991, Elsevier: New York. p. 5-15.
7. Williams, F.H., *A method for more fully determining the outline of the heart by means of a fluoroscope together with other uses of this instrument in medicine.* Boston Med Surg, 1896. **135**: p. 335.
8. Weinberg, S.L., *An Era in Cardiology: A Clinician's View*, in *An Era in Cardiovascular Medicine*, S.B. Knoebel and S. Dack, Editors. 1991, Elsevier: New York. p. 322-324.
9. Davidson, C.J., R.F. Fishman, and R.O. Bonow, *Cardiac catheterization*, in *Heart Disease: A Textbook of Cardiovascular Medicine*, E. Braunwald, Editor. 1997, W.B. Saunders: Philadelphia. p. 177-203.
10. Craige, E., *Should auscultation be rehabilitated?* N Engl J Med, 1988. **318**: p. 1611-1612.
11. Tavel, M., *Cardiac auscultation: a glorious past- but does it have a future?* Circulation, 1996. **93**: p. 1250-1253.
12. Mangione, S. and L. Nieman, *Cardiac auscultatory skills of internal medicine and family practice trainees: a comparison of diagnostic proficiency.* JAMA, 1997. **278**: p. 717-722.
13. Mangione, S., *The teaching of cardiac auscultation during internal medicine and family medicine residency training: a nationwide comparison.* Acad Med, 1998. **73**: p. S10-12.
14. Mangione, S., *Cardiac auscultatory skills of physicians-in-training: a comparison of three English-speaking countries.* Am J Med, 2001. **110**: p. 210-216.
15. Schneiderman, H., *Cardiac auscultation and teaching rounds: how can cardiac auscultation be resuscitated?* Am J Med, 2001. **110**: p. 233-235.
16. Jost, C.H.A., et al., *Echocardiography in the evaluation of systolic murmurs of unknown cause.* Am J Med, 2000. **108**: p. 614-620.

17. Danford, D.A., et al., *Accuracy of clinical diagnosis of left heart valvular or obstructive lesions in pediatric outpatients with heart murmur.* Am J Cardiol, 2002. **89**: p. 878-884.
18. Lok, C., C. Morgan, and N. Ranganathan, *The accuracy and interobserver agreement in detecting the "gallop sounds" by cardiac auscultation.* Chest, 1998. **114**: p. 1283-1288.
19. Weitz, H.H. and S. Mangione, *In defense of the stethoscope and the bedside.* Am J Med, 2000. **106**: p. 669-671.
20. Anderson, R., M. Fagan, and J. Sebastian, *Teaching students the art and science of physical diagnosis.* Am J Med, 2001. **110**: p. 419-423.
21. Medicine, S.o.G.I.M.a.C.D.i.I., *Core Medicine Clerkship Curriculum Guide: A Manual for Faculty.* Version 2.0 ed. 1998, Rockville, MD: Health Resources and Services Administration.
22. Bass, E., et al., *National survey of clerkship directors in internal medicine on the competencies that should be addressed in the medicine core clerkship.* Am J Med, 1997. **102**: p. 564-571.
23. Colleges, A.o.A.M., *Learning Objectives for Medical Student Education - Guidelines for Medical Schools. Medical School Objectives.* 1998, Washington, DC: Association of American Medical Colleges.
24. Wagner, J., *personal communication.*
25. Etchells, E., C. Bell, and K. Robb, *Does this patient have an abnormal systolic murmur?* JAMA, 1997. **277**: p. 654-571.
26. Cook, D.J. and D.L. Simel, *The rational clinical examination. Does this patient have abnormal central venous pressure?* JAMA, 1996. **275**: p. 630-634.
27. Panju, A., et al., *The rational clinical examination. Is this patient having a myocardial infarction?* JAMA, 1998. **280**: p. 1256-1263.
28. Myers, K.A. and D.R. Farquhar, *The rational clinical examination. Does this patient have clubbing?* JAMA, 2001. **286**: p. 341-347.
29. Choudhry, N.K. and E.E. Etchells, *The rational clinical examination.* JAMA, 1999. **281**: p. 2231-2238.
30. Badgett, R.G., C.R. Lucey, and C.D. Mulrow, *The rational clinical examination. Can the clinical examination diagnose left-sided heart failure in adults?* JAMA, 1997. **277**: p. 1712-1719.
31. Folland, E.D., et al., *Implications of third heart sounds in patients with valvular heart disease.* N Engl J Med, 1992. **327**: p. 458-462.
32. Drazner, M., et al., *Prognostic importance of elevated jugular venous pressure and a third heart sound in patients with heart failure.* N Engl J Med, 2001. **345**: p. 574-581.
33. Mangione, S., et al., *A comparison of computer-assisted instruction and small-group teaching of cardiac auscultation to medical students.* Medical Education, 1991. **25**: p. 389-395.
34. Stern, D., et al., *Using a multimedia tool to improve cardiac auscultation knowledge and skills.* J Gen Intern Med, 2001. **16**: p. 763-769.
35. ACC/AHA, *Guidelines for the clinical application of echocardiography.* Circulation, 1997. **95**: p. 1686-1744.

36. Hu, B., F. Saltiel, and R.L. Popp, *Effectivenes of limited training in echocardiography for cardiovascular diagnosis.* Circulation, 1996. **94(Suppl)**: p. I-253.
37. Kimura, B., et al., *Screening cardiac ultrasonographic examination in patients with suspected cardiac disease in the emergency department.* Am Heart J, 2001. **142**: p. 324-330.
38. Vourvouri, E.C., et al., *Experience with an ultrasound stethoscope.* J Amer Soc Echo, 2002. **15**: p. 80-85.
39. Seward, J., et al., *Hand-carried cardiac ultrasound (HCU) device: recommendations regarding new technology.* J Amer Soc Echo, 2001. **154**: p. 369-373.
40. Grenier, M.-C., et al., *Clinical comparison of acoustic and electronic stethoscopes and design of a new electronic stethoscope.* Am J Cardiol, 1998. **81**: p. 653-656.
41. Medicare Education and Training, *What Every Medical Resident Needs To Know About The Medicare Program*. 1999, Baltimore, MD: Health Care Financing Administration.
42. Abrams, J., *Synopsis of cardiac physical diagnosis*. 2nd ed. ed. 2001, Boston: Butterworth-Heineman.
43. Stevenson, L. and J. Perloff, *The limited reliability of physical signs for the estimation of hemodynamics in chronic heart failure.* 1989. **261**: p. 884-888.
44. Leier, C.V., *Masters of Heart Failure Series- Part 2 of 4. Nuggets, pearls and vignettes of master heart failure clinicians. Part 2 - the physical examination.* CHF, 2001. **November/December**: p. 297-308.

Additional Resources:

Auscultation Assistant Website @ www.wilkes.med.ucla.edu/intro.html