This document is a best practices essay from the international, multidisciplinary collection of teaching and training techniques, “Critical thinking and Clinical Reasoning in the Health Sciences.” Each essay in this set provides an example of training reasoning skills and thinking mindset described by international experts in training clinical reasoning.

The Clinical Sieve: a Visual Implement to Share the Diagnostic Thinking

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Dr. Carlos Cuello-García, MD, is a professor of pediatrics and clinical research in the School of Medicine at the Instituto Tecnológico y de Estudios Superiores de Monterrey (ITESM) in Monterrey, Mexico. He directs the Centre for Evidence-Based Medicine (Centro de Medicina Basada en Evidencia del Tecnológico de Monterrey). Dr. Cuello-García uses an interactive pedagogy to teach clinical reasoning using on-line postings of clinical cases. Here he describes a technique for thinking about clinical cases which he terms the “clinical sieve.” This session incorporates teaching students about several key diagnostic reasoning concepts: ‘sensitivity,’ ‘specificity,’ and ‘likelihood ratios.’ The exercise is particularly valuable because it uses authentic problem scenarios and can easily adaptable to clinicians in all areas of the health sciences. This type of reasoning context discussed by Dr. Cuello-García (the need for high stakes judgments under conditions of uncertainty) is an example of what has been termed ‘naturalistic decision-making.’ You can find out more about thinking and decision-making in this type of judgment process in “Naturalistic Decision Making” by Caroline Zsambok and Gary Klein (1997).

Thank you, Dr. Cuello-García, for this most interesting clinical session.

Background
The clinical sieve was developed in the year 2002 when working with pediatric residents and medical students in morning reports and presentations of clinical cases. In the clinical teaching environment the presentation of clinical cases provides a ready opportunity for the healthcare professional apprentice to deal with the process of decision making. He or she must think about the case and present a list of differential diagnoses based on the data provided from a clinical scenario. Using the list of differential diagnoses, they must then move on to decide which of the entities considered is most likely, and what kind of studies are necessary for reaching a definitive diagnosis. Usually this is time consuming and difficult to present to the tutor or to any other clinician. This decision making process usually
involves the use of probabilities of disease or conditions and hence Bayesian reasoning. The clinical sieve can provide a “snapshot” of the thinking process of the clinician at any moment of the “clinician-patient-disease” experience.

The objectives of the clinical sieve

1. To provide an additional educational tool for the presentation of a clinical case in different settings.

2. To assist health professional apprentices in the resolution and presentation of a clinical case by using probabilities of disease and Bayesian reasoning.

3. To encourage the apprentice to use the most relevant and valid information to decide which diagnostic actions will be taken on a particular case.

4. To facilitate the agreement between clinicians when they face a clinical scenario with several differential diagnoses through the visual evaluation of the most and less likely diagnostic possibilities.

The student population and settings

Any healthcare professional presenting a case could make use of the clinical sieve. The following examples suggest how it might be used in clinical teaching settings by both clinical professors and health science students and apprentices:

- After morning rounds in a discussion of the differential diagnosis.
- In a short or long case presentation or oral exam with simulated or real patients.
- In problem-based learning teams, when the team is ready to make a visual presentation of the clinical case.
- As part of an interactive lecture as an opportunity to interact with the audience to increase participation in discussion of the differential diagnosis.

All that is needed is a board, a slide show presentation or any visual adjunctive method that nowadays is used as part of the medical educational practice.
Background to apply the method

The threshold approach by Pauker and Kassirer (1980) is required for the student to understand the process of the clinical sieve. This method is described elsewhere in any evidence-based medicine source (Cuello-Garcia, 2005) and I will give a brief introduction using Figure 1.

In any given clinical case, the probability of a disease or condition must be established by the health professional facing the problem. In Figure 1 you can see a horizontal line depicting the probability of a disease or condition from zero to 100 percent. The line shows that the probabilities are divided into three zones, delimited by two thresholds. Sometimes the probability of a disease is small enough to be in the first zone, this is the zone of certainty of no-disease and it means that the probability of disease is low enough that no diagnostic action should be taken at this moment. Certainly the actual probability is not mathematically equal to zero, but rather it is low enough that for the moment it can be treated as zero. Over time and with changing clinical information, the estimates of probability of disease can change, possibly moving the probability from the zone of certainty of no-disease to the next zone, the zone of diagnostic uncertainty or even to the last zone, the certainty of disease).

The movement of the probability of disease from one zone to another occurs as a result of a critical thinking process, interpretation of the available clinical information, analysis of its meaning and the drawing of an inference as to the relevance of the new clinical information to determine which of the differential diagnoses will explain the illness condition. Thus, this decision process involves the critical thinking skills of interpretation, analysis, inference.

For example, consider a patient with mild stomach-ache where the clinician considers the possibility of an appendicitis to be particularly low, and places this probability in the zone of certainty of no-disease so he or she does not have to perform expensive tests at this moment. Now suppose the patient continues with the tummy ache, a mild fever appears and the patient begins vomiting. Interpreting this new clinical information in terms of its relevance for each of the differential diagnoses will lead to a reassessment of the probability of each. By now the clinician may infer that the probability of appendicitis might be greater than before, hence the clinician must consider the performance of a diagnostic action (like a complete blood count, an ultrasound or a computed tomography). The clinician is in doubt (zone of diagnostic uncertainty) whether or not the patient has the clinical entity in question (in this case appendicitis), but considers that the probability of disease is large enough to perform a diagnostic action.

A diagnostic action is any method, procedure, or test performed to diagnose disease, disordered function, or disability; occasionally even time of observation can be considered a diagnostic process. The main objective is to decide which diagnostic tests will be helpful to get the probability of disease to the first zone, where the patient does not have the condition, or on to the certainty of disease zone. In this zone, the patient has enough signs and symptoms supported by laboratory values or other tests that the clinician now can consider the likelihood of a disease as large enough to consider it a certainty and proceed with treatment, preventive care and/or educational plans.

Continuing the example, suppose the patient with the stomach-ache arrives with a classic perforated appendicitis. In this case a clinician would place the patient in the ‘certainty of disease zone’ immediately, and want to go directly to the operating room and not perform a CT scan or other costly and useless tests. In this case the clinician is relying on the interpretation of the clinical evidence as so highly indicative of the differential diagnosis of appendicitis that he or she feels warranted to infer with confidence that the probability of appendicitis being the true diagnosis can be treated as 100%.

Now consider the two “limits” or thresholds that separate these zones: the first limit is called the test threshold, which is commonly a hazy and clinician-dependent grey zone. It is a decision point and beyond this, a diagnostic action must be taken. A health professional must decide if the disease considered in his or her patient is probable and dangerous enough to perform a diagnostic action, advocating the use of the most relevant and valid information and perhaps group discussion for making this decision. The second is the treatment threshold, also a “grey zone” point of decision.
for the clinician who must choose to pass this threshold once he or she is ready to initiate treatment on the patient, that is, the probability of the disease is plausible that does not need further tests.

Every diagnostic action has a particular “power” to help clinicians move the probability of the disease forward or backwards; this power is called the likelihood ratio which is obtained from the sensitivity and specificity of the test. The last two values are obtained from clinical studies or textbooks. The formula for calculating the likelihood ratio and interpretation of the various values one obtains as a result of this calculation is described in Table I.

<table>
<thead>
<tr>
<th>LR</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 10</td>
<td>Large and often conclusive increase in the likelihood of disease</td>
</tr>
<tr>
<td>5 - 10</td>
<td>Moderate increase in the likelihood of disease</td>
</tr>
<tr>
<td>2 - 5</td>
<td>Small increase in the likelihood of disease</td>
</tr>
<tr>
<td>1 - 2</td>
<td>Minimal increase in the likelihood of disease</td>
</tr>
<tr>
<td>1</td>
<td>No change in the likelihood of disease</td>
</tr>
<tr>
<td>0.5 - 1.0</td>
<td>Minimal decrease in the likelihood of disease</td>
</tr>
<tr>
<td>0.2 - 0.5</td>
<td>Small decrease in the likelihood of disease</td>
</tr>
<tr>
<td>0.1 - 0.2</td>
<td>Moderate decrease in the likelihood of disease</td>
</tr>
<tr>
<td>&lt; 0.1</td>
<td>Large and often conclusive decrease in the likelihood of disease</td>
</tr>
</tbody>
</table>

Table 1. Formula to obtain the likelihood ratios (LR) for a positive and a negative test and the interpretation based on the results. Sensitivity and specificity must be ≤ 1

How to use the clinical sieve in a clinical seminar

I design the clinical seminar to have two parts: an interactive lecture which I lead, and a subsequent clinical team discussion. I usually use the following clinical vignette when explaining the method, but almost any clinical case can be used in different educational settings. With experience you will be able to decide which topic and with what case scenario the sieve can be used.

“Anna is a six-month-old girl that is brought by her parents to the emergency room with fever for the last two days. The past medical history is unremarkable and her immunization schedule is complete. She is attentive, a little fussy but consolable. She doesn’t have a toxic appearance but has a temperature of 41°C (rectally), respiratory rate 45 per minute, pulse 120 per minute, oxygen saturation 98% at room air. The rest of her physical examination is unrevealing.”
My interactive clinical lecture
The participants are gathered around a whiteboard and I let them read the case that I prepared (the vignette above). I also ask them to read in advance the topic (in this case, fever in children from 0 to 36 months old) so we could make a more interactive lecture. I start asking them the relevant data from the patient so they can construct a list of problems. This is best performed if they discuss the relevant data, the signs and symptoms and if they can construct a syndrome with the current information. The students review the case and begin to state out loud the problems that they considered to be “activating findings” as described in the work of Custers and co-workers (Custers, Stuyt & De Vries Robbe, 2000) that is, all the information that has diagnostic or therapeutic potential is presented and then portrayed as a problem in a list. Meanwhile I write them down as presented in Figure 2 so the group could see the patient in one piece.

<table>
<thead>
<tr>
<th>Chief complaint</th>
</tr>
</thead>
<tbody>
<tr>
<td>“fever in my child”</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>List of problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fever &gt;39° C.</td>
</tr>
<tr>
<td>Irritability</td>
</tr>
<tr>
<td>Lack of appetite</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Syndromes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fever without localizing signs</td>
</tr>
</tbody>
</table>

Figure 2: The problem representation
The participants obtain a chief complaint, list of problems and syndromes

After the group completes and evaluate the list of problems, I ask for the differential diagnosis. The apprentices must initiate a brainstorming session. Brainstorming is a technique used to get all potentially relevant ideas on the table. It involves the verbalization of inferences made in response to a particular prompt, in this case the request for possible differential diagnoses. When brainstorming, one does not typically interrupt the process to evaluate or challenge the strength of the inference that led someone to propose an idea, but on occasion this is necessary to avoid the problem of subsequent inferences moving farther and farther away from the objective: to obtain a working list that can guide further thinking.

The tutor could (and usually should) guide the students in a certain order in the process of building the list of problems as in the brainstorming session of the differential diagnoses list. I do this by helping them to organize their thinking into several categories as I write down the conditions as they come up with them. The list of possible diagnoses can be ordered by etiology, organs affected, pathophysiology, anatomy, etc. In this example they preferred to order the list in etiologic groups as they read in a review article last night. I usually end up with a list like the one in Figure 3.
In the next step I say “Determine the probability of every condition that you considered in your patient (in this case, Anna).” I encourage the team to ask: “What is the probability of occult bacteremia?” “What about the probability of a urinary tract infection? Meningitis? Pneumonia?” “Briefly describe each one of the diseases” “Which is more likely?” “Which is more dangerous?” “How would you manage the thresholds for each one of them? Think and apply the test threshold in each possibility.” “Is it possible that the patient could have two or more clinical entities explaining the process?” In each case I require them to explain their answers.

Each of these questions initiates a thinking and decision process that demands the use of critical thinking skills, in this case emphasizing the skills of analysis, inference and explanation. The assignment of probability is another critical thinking process, emphasizing the skills of analysis, inference and evaluation.

**Clinical Team Discussion:**

At this point the visual part and the discussion begins. The group has to get to an agreement by applying the threshold method that we described earlier to each of the diagnostic possibilities.

Which entities are probable and dangerous enough to pass to the uncertainty zone (analysis and inference)? This question is usually a clinical challenge and it’s a very important step in the whole process. Keep in mind that the team will have to perform a diagnostic action if the probability of disease is in the uncertainty zone. By diagnostic action I mean anything from a dangerous, costly and uncomfortable procedure (like a lumbar puncture or a cardiac catheterisation) to a simple and inexpensive process (like just leaving the patient in the observation room). This question makes the student consider patient preferences and values, solid clinical evidence and their own clinical experience by balancing costs, pain and time using the critical thinking skills of evaluation and explanation. The team will ponder their own efficacy, efficiency and effectiveness.

Using defining and discriminating features the team begins to discuss why this patient could have or not have each one of the diseases that they considered in their differential diagnosis, and how likely is each one of them. As they tell
me I write a line in front of every condition and they advise me how long (probable) or short must be, and if the possibility is large enough to “pass” to the uncertainty zone or even to the certainty zone of disease. In the course of this discussion they must say what evidence they are using to determine the length of the line (answering the key critical thinking questions: “Why do I/you come to this conclusion”). According to the probabilities that they considered after activating their previous knowledge based on a recent review, they finally decided that Figure 4 would be the initial visualization of the problem.

As you can note, according to the students appreciation, there are several diagnostic possibilities that they have placed in the uncertainty zone, and hence they will ask for a diagnostic action only for those probabilities that are positioned in this area. At this moment, the team sees a patient with a viral infection as the most likely explanation for her problems, but they cannot reject the possibility of a urinary tract infection or an occult bacteremia, because they presented evidence that there is a 7% and 3% chance of them respectively. For them this probability was high enough to pass these two conditions to the uncertainty zone, but it was not the case for the other conditions, at least not for the moment (for example, they did not consider to perform a lumbar puncture to rule out meningitis or a chest x-ray for pneumonia). The next step is to perform

![Figure 4: Clinical sieve, first agreement by the students.](image)

Important note: for visual reasons, the lines of the test and treatment threshold are represented as two vertical lines, but these thresholds are different in every diagnostic possibility (i.e., the occult bacteremia threshold might be low because it is a precarious entity, contrary to the viral infection which is harmless, so its threshold could be more relaxed).
the diagnostic actions for the conditions in the uncertainty zone, but as in the previous step, they have to consider availability of the test, costs, pain, timing, diagnostic accuracy and easiness for the patient or family.

When defining the diagnostic actions for each condition in the uncertainty zone, they decided that a complete blood count, a blood culture, urinalysis and a urine culture would be sufficient for the moment. Sometimes one student might ask for a completely out of context test (for example, a Widal test for ruling out a typhoid fever) but he or she would be questioned by the rest of the group when they do not see this disease as part of the sieve and even if it was, they would not put it into the uncertainty zone. The group process offers the opportunity for the demand for a critical thinking explanation of this conclusion to come from the learner rather than the professor. The group makes the point that if, at this point, the speaker would like a new diagnosis (and therefore a new test) in the uncertainty zone, they will have to give solid data to back their opinion.

Sometimes, evidence about a condition or hypothesis will be limited, and clinical intuition could be used at this point in the clinical sieve and give the team a moment to reconsider the case and critically think about the possibility of any bias or heuristic that any clinician in a real life case would use. Experienced clinicians often unconsciously use several, combined analytic and non-analytic strategies to solve clinical problems suggesting a high degree of mental flexibility and adaptability in clinical reasoning (Bowen, 2006), and the expert could discuss along with the team how she or he would have portrayed the differential diagnosis in the sieve and why. When the evidence (i.e., diagnostic accuracy, sensitivity or specificity) about a given diagnostic test is not available at all, the team should not see this as a burden but as an opportunity to continue the search for the truth and promote their interest for clinical research.

<table>
<thead>
<tr>
<th>Test</th>
<th>Results</th>
<th>LR Positive Test</th>
<th>LR Negative Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBC</td>
<td>WBC 18,000</td>
<td>3.7</td>
<td>N. A.</td>
</tr>
<tr>
<td></td>
<td>ANC 12,000</td>
<td>3.5</td>
<td>N. A.</td>
</tr>
<tr>
<td>Urinalysis</td>
<td>Gram stain is positive</td>
<td>18</td>
<td>N. A.</td>
</tr>
<tr>
<td></td>
<td>15 wbc/mm³</td>
<td>7</td>
<td>N. A.</td>
</tr>
<tr>
<td></td>
<td>LE and nitrites negative</td>
<td>N. A.</td>
<td>0.5</td>
</tr>
<tr>
<td>Blood culture</td>
<td>N. A.</td>
<td>N. A.</td>
<td>N. A.</td>
</tr>
<tr>
<td>Urine culture (bladder catheterization)</td>
<td>N. A.</td>
<td>N. A.</td>
<td>N. A.</td>
</tr>
</tbody>
</table>

Figure 5: Diagnostic actions taken by the students and test results with their respective likelihood ratios (LR).

CBC= complete blood count. WBC, white blood cells. ANC, absolute neutrophil count. N.A., not available. L.E., leukocyte esterase.

During the team discussion, I have been generating the list of the clinical tests that will be requested by the team as a result of the assigned probabilities of each differential diagnosis in the uncertainty zone. My job is also to guide the discussion when necessary be sure that the final list approximates the optimal list of the experienced clinician. When possible, the team (or the tutor) provides the value of the likelihood ratio obtained from the sensitivity and specificity from clinical trials or from textbooks. This encourages the team to ask good clinical questions and search for the most
valid and relevant information. The timing of this clinical team discussion, searching to answer the clinical questions in this case, is the decision of the tutor. On occasion, I split the lecture into two parts to give the student time to search for the data between class sessions. Once the request for diagnostic tests is complete, I expose the results for the case (Figure 5).

In the next step the team must develop a second sieve depicting how their diagnostic possibilities changed based on the present evidence. At this point, altogether they will apply Bayesian reasoning, that is, using the present evidence (the likelihood ratios of the tests) to move the pre-test probabilities after a diagnostic test result is presented. For example, in the case of a urinary tract infection, the urinalysis test shows a positive gram stain. One of the students had read (and showed an article) that a positive gram stain has a likelihood ratio of 18. This evidence is strong enough to move forward the probability of a urinary tract infection (see Table I). If the tutor or the team would like to be more specific they could use the nomogram of Fagan to accomplish an exact result of the post-test probability (Fagan, 1975). The tutor should now ask the team: “How have these test results changed your view?” “What do you think now?”

The team usually ends up with a schematic like the one in Figure 6, and as expected, the probability of a urinary tract infection (UTI) is in the certainty zone of disease, that is, the team is sufficiently sure about this diagnosis that is ready to move to the treatment plans, thanks to the high likelihood ratio given by the positive gram stain. The LR positive of 18 gave a post-test probability of 60% for the patient of having a UTI.

Viewing the second sieve the team is not yet sure if the patient has bacteremia, thus they will have to wait for the results of the blood culture. Concerning the UTI, they will not wait for the results of the urine culture just as they considered a 60% chance of the disease is enough to initiate the antibiotic (i.e., prophylaxis). The lecture can continue from here, discussing the other part of the therapeutic plans, which include preventive, educational and further diagnostic plans.
Conclusion

In real life a clinician almost never will have a 100% assurance about a diagnosis, but certainly he or she will almost be sure about one or two possibilities in a given case. Clinicians mostly use some heuristic to rapidly explain a clinical problem. Resolving a clinical case is a complex process involving a high level of meta-cognitive events.

Any health professional in the teaching environment could make use of the clinical sieve as a visual tool for sharing the diagnostic process. It blends clinical reality and diagnostic reasoning, encouraging the use of clinical judgment and evidence on which diagnostic tests would be helpful, and attaining agreement by scientific discussion among health-care professionals. In terms of critical thinking, it demands reason-giving by the thinker and the thinking team at each stage of the exercise. It can help clinicians in training to interpret evidence, graphics, probability questions, pros and cons for a diagnostic test and drawing judicious and non-fallacious conclusions.

Learners should be encouraged to read about their patients’ problems and present the situation to their teachers in a way that promote the skills of critical thinking, rather than to present clinical cases without context and read about topics in a rote-memorization fashion.

References


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