

Are Bad Outcomes from Questionable Clinical Decisions Preventable Medical Errors? A Case of Cascade Iatrogenesis

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When a patient with multiple, complicated conditions is admitted to a hospital and risky procedures are performed that result in adverse outcomes, the difficulties inherent in determining whether and when a preventable medical error has occurred must be addressed. This article analyzes the case of a 40-year-old woman with a history of chronic aortic dissection and pericardial effusion who was admitted to a teaching hospital with unilateral swelling of her left breast and arm accompanied by dyspnea. During her hospitalization, the patient developed multiple complications from the diagnostic and therapeutic procedures that were performed. The authors argue that this case illustrates some limitations of routinely undertaking time-consuming and costly reviews, or "root-cause analyses," as a patient safety strategy when they are unlikely to reveal remediable "errors" or to suggest better systems of care that will prevent errors. The ability to establish causality

through post hoc reviews is the linchpin in the recommendation for widespread adoption of error reporting and reviews. When causality is not established, it is impossible to know whether any changes adopted as a result of the reviews will be effective. This case, in which the causal pathways to the adverse events are very uncertain, may be much more typical than the egregious errors featured in a classic root-cause analysis. The authors recommend that the relative merits of this approach to patient safety be compared with other proven, cost-effective interventions to improve quality, such as appropriate treatment of myocardial infarction or depression, before scarce resources and enormous human capital are allocated for widespread implementation.

Ann Intern Med. 2002;137:327-333.

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"Quality Grand Rounds" is a series of articles and companion conferences designed to explore a range of quality issues and medical errors. Presenting actual cases drawn from institutions around the United States, the articles integrate traditional medical case histories with results of root-cause analyses and, where appropriate, anonymous interviews with the involved patients, physicians, nurses, and risk managers. Cases do not come from the discussants' home institutions.

CHRONOLOGY OF EVENTS

Whitney Dobsen (a pseudonym), a 40-year-old woman with a history of type B aortic dissection and renal insufficiency, was admitted to the medical service of a teaching hospital for evaluation of dyspnea and swelling of her left breast and arm. During her hospitalization, Ms. Dobsen developed multiple complications from the diagnostic and therapeutic interventions that were performed.

The patient's medical history included poorly controlled hypertension, which was complicated by erratic adherence and cocaine use, and chronic renal insufficiency. In addition, a type B aortic dissection, diagnosed 6 months before this hospitalization, was being treated medically. The patient's long-term medications included metoprolol, minoxidil, benazepril, nifedipine, and clonidine. A large but hemodynamically insignificant pericardial effusion had been noted several months earlier. The patient's nephrologist attributed this complication to minoxidil.

Three days before admission, Ms. Dobsen noted pain and swelling in her left breast and arm. She also reported a dry cough associated with shortness of breath. She denied having chest pain, nausea, vomiting, weight loss, or fever. On physical

examination at admission, the patient appeared generally well but had moderate tachypnea with a respiratory rate of 25 breaths per minute. Her temperature was 37.5 °C, her pulse was 100 beats per minute, and her blood pressure was 180/110 mm Hg. Of note during the examination were prominent inspiratory crackles in the left lower lung, normal jugular venous pressure, and an S₄ gallop. The left breast appeared mildly swollen, and there was mild pitting edema of the dorsal left hand.

Laboratory results showed a leukocyte count of 11.1×10^9 cells/L, a hematocrit of 0.302, a chronically elevated blood urea nitrogen level of 6.78 mmol/L, and a creatinine level of 247.5 μ mol/L (2.8 mg/dL). Chest radiographs showed a left lower consolidation that was consistent with multisegmental atelectasis or pneumonia. Electrocardiography revealed sinus rhythm, with unchanged, nonspecific lateral ST-segment and T-wave changes.

At initial presentation, the findings seemed to be most consistent with deep venous thrombosis of the left upper extremity and pulmonary embolism associated with a hypercoagulable state due to possible left-sided breast cancer. A spiral computed tomography (CT) scan was initially read by the radiology resident as negative for pulmonary embolism; however, the next morning, the scan was reevaluated by the attending radiologist, who identified segmental emboli in both the right lower and left upper lobes, chronic type B aortic dissection, and a "huge pericardial effusion."

The patient was treated with intravenous heparin and oral warfarin. Mammography revealed no evidence of breast cancer, and ultrasonography of the left arm found no deep venous thrombosis.

*This paper was prepared by Timothy P. Hofer, MD, MS, and Rodney A. Hayward, MD, for the Quality Grand Rounds series. Kaveh G. Shojania, MD, and Sanjay Saint, MD, MPH, prepared the case for presentation.

Over the next several days, the patient felt somewhat better but still reported intermittent dyspnea and cough. Her respiratory rate decreased to 15 breaths per minute, but she continued to require 2 to 3 L of oxygen to maintain normal oxygen saturation. The swelling of the left breast and arm diminished but did not entirely resolve.

One week after admission, the patient remained hospitalized because of a slow anticoagulant response to warfarin. After mammography ruled out breast malignancy, she was evaluated for a hypercoagulable state, which was not found. A consulting hematologist suggested that the patient's left-sided subclavian catheter, which had been inserted during a previous hospitalization, placed her at increased risk for thrombosis or stenosis, but magnetic resonance imaging of the chest and arm ruled out thrombosis and pulmonary embolism. The study did suggest nonthrombotic stenosis of the mid-left subclavian vein and documented the known type B aortic dissection and "massive pericardial effusion."

Echocardiography also confirmed the large pericardial effusion (slightly increased compared with the results of echocardiography performed 6 weeks earlier) with "equivocal early tamponade physiology." In addition, an attending radiologist with special expertise in imaging pulmonary emboli reevaluated the CT scan done at admission (the re-review was done as part of a research study) and found it to be negative for pulmonary embolism.

AN ERROR OR NOT AN ERROR?

A 1999 report by the U.S. Institute of Medicine (1) claimed that between 44 000 and 98 000 hospital deaths per year in the United States were due to medical errors. The report generated calls for action from former President Clinton and Congress (2, 3) and a vigorous debate in the medical literature (4–6). Although studies find moderate agreement between independent assessments of adverse events (7), judgments regarding whether such events were preventable or involved negligence vary greatly (7–11). (The **Appendix Table**, available at www.annals.org, provides general definitions found in studies and discussions of medical errors.) Moreover, many events described as preventable errors may actually exert little impact on patient prognosis, at least in hospitalized patients who already have multiple acute and chronic conditions that affect their short-term prognosis (5, 11). When confronted with a case of a patient injury caused by administration of the wrong drug (12) or the performance of an invasive procedure on the wrong patient (13), few would debate branding the incident as a "preventable adverse event" and searching for ways to prevent it (14). The issues raised by this case, however, are murkier and, undoubtedly, more common.

DIAGNOSTIC TESTING

At this point, the case raises two well-described quality issues: 1) Can we improve the reliability and accuracy of the interpretations of diagnostic tests, such as radiography;

and 2) should we regulate the introduction and use of new diagnostic technologies?

As all clinicians realize when initial "wet reads" and final readings diverge, the interpretation of radiographic studies is prone to variation. It is tempting to blame erroneous wet reads on radiology trainees. In this case, however, the final expert reading agreed with the initial reading by the resident and not the interpretation of the staff radiologist. In absolute terms, interobserver agreement in radiograph interpretation is often only moderate (κ values of 0.3 to 0.6 in studies of mammography and spinal magnetic resonance imaging) (15–17). The prevalence of poor outcomes from such disagreement is unclear (18, 19). Based on currently available evidence, mandating routine independent readings by multiple radiologists (20) seems unlikely to be worth its substantial expense. However, a low threshold for seeking a second opinion seems appropriate when test results are crucial or the interpretation is uncertain.

A general strategy for improving the reliability of radiograph interpretation is to develop better preestablished criteria for separating "positive" readings into more meaningful, probability-based interpretations, such as "high," "moderate," and "low." One of the few areas in which this has been done is in the work-up of suspected pulmonary embolism (21, 22). Ventilation–perfusion scans, lower-extremity investigations for deep venous thrombosis, and pulmonary angiography all have well-established test characteristics (23, 24). Validated algorithms for combining results of these tests with clinical factors to generate reasonably accurate "post-test probabilities" also exist (25, 26). Thus, it is ironic that the most notable "error" at this point in our case involves the interpretation of a spiral CT scan obtained in the evaluation of suspected pulmonary embolism. Despite the rapid dissemination of spiral CT for the diagnosis of pulmonary embolism, at the time of this case, the literature did not yet provide data on variations in interpretation and overall reliability, as exists for more traditional tests, such as ventilation–perfusion scanning (27, 28).

This case also raises questions about the introduction of new medical technologies. The patient had a relatively new diagnostic test, spiral CT, instead of the well-studied ventilation–perfusion scanning or the gold standard, pulmonary arteriography. Considerable diagnostic uncertainty resulted. Although health care technology assessment is an established discipline (29–31), the rapid integration into routine use of spiral CT scans demonstrates the extent to which new diagnostic technologies become routine practice in advance of strong supporting evidence (27, 32).

To return to the clinical details of the case, this patient's pretest probability of pulmonary embolism is somewhat difficult to assess because the clinicians seemed most impressed by the left arm swelling, which they attributed to upper-extremity deep venous thrombosis. Estimates of the risk for pulmonary embolism in patients with upper-extremity venous thrombosis vary widely (33–36). In this

case, the patient's overall clinical picture seemed consistent with an at least moderate, if not high, pretest probability of pulmonary embolism (26). Therefore, further investigation of pulmonary embolism would have been justified, particularly in light of the indeterminate ventilation–perfusion scan (a likely result of the left lower lobe consolidation) and negative ultrasonography results. The clinicians may have rejected the gold standard pulmonary arteriography for fear that its dye load would further compromise the patient's renal function and, perhaps, because they were unaware that a spiral CT scan delivers a comparable dye load (37). At this point in the review, we are left with the questionable, albeit understandable, decision to use a spiral CT scan and a more general reminder of the importance of standardizing the assessment and introduction of new diagnostic technologies.

CHRONOLOGY OF EVENTS, CONTINUED

After 1 week of hospitalization, the team—having ruled out pulmonary embolism and preparing for possible pericardiocentesis—decided to discontinue Ms. Dobsen's anticoagulant medication. At the nephrologist's suggestion, minoxidil therapy was also discontinued in case it was contributing to the pericardial effusion. Test results for thyroid-stimulating hormone and antinuclear antibody were normal.

At this time, the patient reported less dyspnea, was breathing comfortably at 20 breaths per minute, and had an oxygen saturation of 98% on room air. Her blood pressure was 150/80 mm Hg, with a pulsus paradoxicus of less than 10 mm Hg and a pulse of 80 beats per minute. There was no significant jugular venous distention. The swelling of the arm and breast had improved. A vigorous debate arose as to whether pericardiocentesis under echocardiographic guidance was warranted. The renal consultant did not favor the procedure and felt strongly that the effusion was attributable to minoxidil and may have worsened because of the recent administration of anticoagulant drugs. The consulting cardiologist was impressed by the lack of a clear explanation for the presenting symptoms of dyspnea and arm and breast swelling, the size of the effusion, and echocardiographic evidence of possible early tamponade. Also, it was Thursday afternoon, and he felt that an elective pericardiocentesis on Friday would be preferable to a possible emergent weekend procedure. The attending physician (the physician-of-record) was "not enthusiastic" about the procedure, but ultimately decided that the combination of the echocardiography results and the cardiologist's recommendation "left us with little recourse to the tap." Unfortunately, the residents had forgotten to discontinue the patient's anticoagulant therapy the previous evening, and the procedure was delayed until after the administration of fresh frozen plasma and the documentation of a relatively normal coagulation panel. The procedure was performed on Friday at 7:00 p.m. by a cardiologist other than the one originally scheduled. This cardiologist was also extremely experienced and competent in the procedure. The full complement of catheter-

ization laboratory personnel was in attendance. At the time of pericardiocentesis, the patient's international normalized ratio was 1.3 and her partial thromboplastin time was within normal limits.

Because of the patient's enlarged liver, her moderate obesity, and the position of the effusion, pericardiocentesis was performed by using the apical approach, and 100 mL of bloody fluid was aspirated. The procedure was complicated by creation of a hemopneumothorax (probably due to laceration of the intercostal artery), leading to cardiac arrest with pulseless electrical activity. The patient was successfully resuscitated after 10 minutes with insertion of a chest tube and evacuation of more than 1 L of bloody fluid. She was taken to the operating room, where a pericardial window was created and pleural and pericardial drains were placed.

HINDSIGHT BIAS

Was performing pericardiocentesis an error in general, and, in particular, was it wrong to perform the procedure on a Friday evening? Once again, we are faced with a decision that, even if problematic in retrospect, does not suggest a preventive system solution. By contrast, the failure of the physicians to discontinue anticoagulation represents a clear error of omission. Several approaches have been suggested to decrease medication errors, such as computerized order entry (38), stop orders, or inclusion of a pharmacist on clinical teams (39). Although seemingly attractive, the substantial cost and possible untoward effects of such interventions argue for rigorous evaluation (particularly as to their impact on patient outcomes) before widespread implementation is recommended.

A certain amount of ambiguity surrounds any decision to perform a nonemergent invasive procedure during "off hours." When complications occur, the temptation to second-guess the decision is strong, with hindsight bias exerting its well-known influence (40, 41). Given the outcome, in retrospect, the observer is tempted to label the pericardiocentesis an error of *commission*, arguing that watchful waiting would have been the more reasonable alternative: "The patient's symptoms were stable. They should have just discontinued the minoxidil and observed her closely for signs of improvement." Of course, if the physicians had waited and the patient had experienced cardiac arrest due to tamponade over the weekend, we might well have found ourselves implicating an error of *omission*: "The effusion was large and persistent, with echocardiographic evidence of hemodynamic compromise. Timely pericardiocentesis during the week would have prevented this adverse event." Thus, can we say that any intervention to prevent this decision would have improved overall outcomes? Even if we feel that it would have, extrapolation from anecdotal cases is risky unless performed within a formal evaluative framework (42–44).

CHRONOLOGY OF EVENTS, CONTINUED

The patient seemed to recover from this episode, but several evenings later, she developed right-sided pleuritic chest pain and relative hypotension. The residents on the team were aware that the patient's mediastinal drain had been removed 2 days earlier but reasoned that a recurrent pericardial effusion was highly unlikely after the recent creation of a pericardial window. They again considered the possibility of pulmonary embolism, initiated intravenous heparin, and ordered a repeat spiral CT scan, the results of which were pending.

Later that morning, the patient's attending physician discontinued therapy with the anticoagulant medication. Emergency echocardiography revealed a large thrombus in the pericardium that was compressing the left atrium. During echocardiography, the patient suffered a second cardiac arrest with pulseless electrical activity. She underwent an emergency sternotomy in the intensive care unit, during which the pericardial clot was evacuated and a laceration of the left ventricle was repaired. It was unclear whether this laceration was created during the initial catheterization or the subsequent pericardiocentesis. Postoperative electrocardiography revealed diffuse ST-segment elevations consistent with pericarditis.

On day 2 in the intensive care unit, the patient developed R-on-T phenomenon, followed by torsade de pointes tachycardia and subsequent pulseless ventricular tachycardia that required intubation, defibrillation, and the initiation of amiodarone therapy. Laboratory results revealed worsening renal function and metabolic acidosis, which ultimately required dialysis.

ASKING FOR HELP

At first glance, the decision to discount the possibility of tamponade and restart anticoagulation struck us as the case's worst decision. Yet even here, it may be difficult to achieve consensus about whether this decision was an "error," much less about how an error could have been prevented.

The specific clinical issue—the likelihood of recurrent tamponade after creation of a pericardial window—is probably beyond the expected knowledge base of even a fully trained general internist. For example, we could not find this issue addressed in major textbooks of internal and hospital medicine (45–47). If the residents committed an error, it was in failing to appreciate their limitations and the need for consultation. Although this particular problem could be viewed as an issue of "supervision," the difficulty of deciding when to obtain a consultation challenges all physicians (48), not just housestaff, and represents an important policy issue for numerous areas of medicine (49). The issue of recognizing the need to ask for help (from colleagues or consultants) may be important in future patient safety research. We can easily imagine that the common use of descriptors, such as "strong" and "weak," for students and residents would contribute to an environment that has been shown in other settings to dis-

courage trainees from requesting assistance or guidance, even in the face of excessive work in unfamiliar situations (50, 51). This unfortunate effect may be partially counteracted by promoting the sometimes forgotten professional ethic of never denigrating colleagues, staff, or trainees who ask for help. In the only published report that we found of an evaluation of mandatory consultation (52), the researchers found that this intervention had no effect.

CHRONOLOGY OF EVENTS, CONTINUED

Fortunately, the patient recovered. She was discharged from the hospital on long-term dialysis. Although she probably would have ultimately required dialysis, the complications she experienced accelerated her progression to end-stage renal disease. In the end, the physicians involved in the case attributed the pericardial effusion entirely to the minoxidil, and her dry cough at admission (a prominent symptom during her first week of hospitalization) to use of an angiotensin-converting enzyme inhibitor. Her hospitalization lasted 27 days, and her total hospital charges were \$212 439.

LIMITATIONS TO A COMMONLY PROPOSED PATIENT SAFETY PARADIGM

To date, much of the patient safety movement's emphasis has focused on the mandatory reporting of errors, the performance of a retrospective analysis to illuminate their nature and causes, and systematic changes to prevent error recurrence. Although the true number of adverse events due to medical errors has been debated (5, 6, 11), this model of error reporting and analysis has not been widely challenged in the literature. The most commonly advocated form of retrospective review is a "root-cause analysis," a variably defined and performed intervention. The goal of root-cause analysis is to uncover all of the causal pathways involved in producing a problem, including underlying organizational factors or "root causes" (53, 54). Yet, untangling causal relationships from isolated case reports is problematic. Furthermore, investigating just the fatal adverse events claimed in the Institute of Medicine report would cost well over \$500 million yearly, given estimates of direct personnel costs of the typical root-cause analysis being about \$8000 (55). Any actions precipitated by these investigations could multiply this total manyfold. Substantial expenditures may be justified, but only if they yield demonstrable improvements in patient outcomes.

What might a root-cause analysis of this case have yielded in terms of improved systems of care? This patient suffered multiple adverse events in a manner consistent with cascade iatrogenesis (56, 57). Despite the multiple opportunities for identifying errors in the patient's care, the decisions or circumstances associated with these adverse events (for example, the cognitive decision to pursue pericardiocentesis or the technical performance of the procedure) contributed to the outcomes in very uncertain ways

and, thus, are not easily classified as errors. In this case, the examples of more general problems existing in the U.S. health care system have already been documented by more systematic study. These include poor regulation and overuse of certain tests and procedures as well as medication errors.

The ability to establish causality through post hoc reviews is the linchpin in the recommendation for widespread adoption of the patient safety paradigm. As McDonald and colleagues pointed out (5), in all the studies cited by the Institute of Medicine, it is not clear whether the reported “errors” are correlated with an increased death rate (no studies provide comparison groups), much less whether they caused deaths (11, 44). This difficulty in establishing causality makes it hard to assess whether we should implement solutions that are suggested by root-cause analyses in all but the most egregious cases, such as wrong-site surgery (13). Our personal research experience (10, 11, 44) and the low reliability found in almost all reviews of negligence and poor hospital quality ($\kappa = 0.2$ to 0.4) (10) suggest that the clear-cut cases that make headlines are rare, at least compared with cases like this one.

By illustrating the ambiguities and uncertainties in a single case, we do not mean to suggest that it is worthless to monitor or undertake case-based analysis of adverse events. Such analyses may generate hypotheses, deepen understanding, and suggest system factors that contribute to both adverse events and the potential changes that may protect against them. There are, however, many clear examples from industry of harm resulting from “protective systems” implemented as a result of retrospective reviews (58, 59). If the recommendations of a root-cause analysis are based on an unreliable assessment of causality, there is a significant potential for harm without the potential for benefit. Before devoting tremendous resources to mandatory reporting and root-cause analyses, we should more rigorously evaluate how well this approach works and how this intervention compares with other ones that we could choose.

PRIORITIES FOR ENHANCING PATIENT SAFETY

So where should we devote our efforts to improve patient safety (60)? First, we should insist that proven, cost-effective interventions be implemented. Failure to do so leads to preventable adverse events and clearly reduces patient safety (the freedom from accidental or preventable injury). Rather than attempting to develop universal error-reporting systems, we believe that patient safety may be better enhanced by vigorously promoting use of anticoagulation for high-risk patients; early revascularization for acute myocardial infarction; smoking cessation; colon cancer screening; and appropriate management of diabetes, depression, hypertension, schizophrenia, and hypercholesterolemia. Second, we should work on developing and

evaluating interventions directed at problems already identified in large systematic studies, such as medication errors, undertreatment of pain, timely delivery of life-saving treatments (such as antibiotics for sepsis and thrombolytic agents for myocardial infarction), and overuse of many procedures (1, 12, 61–65). Third, we should devote more effort to investigating the causes, both cognitive and procedural, of common adverse events. As part of this effort, we should undertake several large-scale programs that evaluate patient safety using multiple methods and that follow a rigorous implementation model, such as that introduced in the Department of Veterans Affairs (66). We suggest that these efforts use sound methods that are based on adequate numbers of cases (44, 67, 68) and should not make broad inferences from individual cases. We must also be careful not to focus solely on the hospital, because greater public health benefits will often be found by promoting preventive care and comprehensive care for patients with chronic illnesses (64, 65, 69, 70).

The momentum developed in the patient safety movement presents an important opportunity to highlight quality problems and to work cooperatively to improve patient outcomes. However, as this case demonstrates, it may be difficult to agree when errors occur and even more challenging to develop workable and cost-effective approaches to their prevention. Reviewing individual cases has its uses, but we must not abandon rigorous methods and approaches to quality measurement and improvement in a naive quest for quick and easy answers. Finally, in our view, this case illustrates that not all errors are “system errors.” Although carefully evaluated error-reducing systems are an important and essential part of health care delivery, for many problems in medicine, fostering individual professional skills, expertise, values, responsibility, and accountability remain the best available approach to patient safety.

QUESTIONS AND ANSWERS FROM THE CONFERENCE

Dr. Mark Smith (Moderator): Is there a way in which the systematic knowledge of medicine might be made more readily and ergonomically available to providers? If you don't know if a pericardial window can clog up, is there a way to find out, rather than depending on the next person you ask to be more authoritative than yourself? Is that a potential solution to some of these issues?

Dr. Hayward: Yes, and we see a lot of progress there. Five years ago, we were really held captive to textbooks, which tend to be several years out of date. Now we have more on-line resources, and search engines make it easier to find answers. However, we need to develop systems that are smart enough to deliver information when we are paying attention, because if we get too much information too often, we'll simply hit the escape key.

A Physician: We've discussed a number of solutions or potential solutions to quality problems, including comput-

erized order entry systems, pharmacists on rounds, and more attending availability. All of those things cost money. What's the business case that will make this happen? My pushing you on this comes from the fact that none of the data in the IOM report were new—so what is it going to take to make all these changes happen?

Dr. Hayward: There will be certain errors that are so egregious that we're not going to worry about the money, because they make us all feel unsafe. We can argue—just like we did when that little girl fell down the well in Texas—that spending all that money when other kids haven't been immunized doesn't make sense, but we're going to save her. We are going to make an effort to be sure that people don't get the wrong leg amputated, because thinking about that possibility makes us feel so bad. But in terms of prioritizing these other problems, we should consider which quality problems cause the most preventable disability, whether it's undertreatment, overtreatment, or misuse.

A Physician: There have been calls for reporting of medical errors, whether confidential or nonconfidential. In the context of this case, which is somewhat complicated and arguable about judgment issues versus errors, what are your thoughts about reporting systems?

Dr. Hayward: I'm of mixed minds. I think we should experiment with reporting systems, but I don't think we should invest huge amounts of money yet. I am concerned that we will spend money without a lot of benefit. So, I favor small experiments initially, to see if we're improving safety before investing larger sums.

A Physician: I wonder whether attending oversight in the immediate postoperative period or on attending teaching rounds the following morning would have caught the potential for recurrent tamponade. If this had been raised as a known complication by an attending, either the house-staff or the nursing staff would have been on alert for something like this occurring.

Dr. Hayward: There is that possibility, but where would we put that warning so that it would be seen by all the relevant providers? We know that it is quite difficult to create a system in which the key information is available and in your face at the time that you need it. In fact, this team did round together. The errors weren't from the decision, even if they were errors; some of these were just tough decisions. The pericardiocentesis was discussed at the highest level—right? Two very experienced attendings made that decision. The attending, on rounds, said, "Stop the heparin," and they [the residents] said "sure thing" and then it got lost on their checklist. So, how do you solve that? You might solve that by making it easier to write the stop order. Or you might solve it by having a pharmacist on the team, so that you have two people who know that heparin should be stopped, but it isn't easy.

An Attending Cardiologist: There is a general move afoot toward accreditation of laboratories performing tests, and credentialing of individuals who interpret tests. We see

this in my field, which is echocardiography, and also in vascular laboratories. What kind of impact do you think that will have, and do you think that it is a worthwhile endeavor?

Dr. Hayward: Yes. I tend to be a fairly big advocate of specialization, especially for procedures that have substantial morbidity or where big decisions are based upon them. I think this is a trend throughout time. I think we've made progress but not as much progress as in other countries. People from Canada and Europe think that we are crazy to have so little centralization. In Michigan, the average person doing carotid endarterectomies does fewer than 40 a year. I think that is a mistake. There's no economy of scale. The question is when to insist that physicians performing specialized functions take proficiency exams. The exams are probably not as important as ongoing quality monitoring improvement. I believe that effective systems will allow physicians to learn, not just to do a lot of procedures poorly but to do a lot of them better and to let people learn from each other. In addition to the focus on procedures, I also think we need a lot more research on diagnostic studies. We do a lot of diagnostic tests but we do very little research to systematize the interpretation of these tests. The work on systematizing the readings of V/Q scans in the work-up for pulmonary embolus has done a lot of good, and I think we can do that in other areas as well.

Glossary. General Definitions Found in Studies and Discussions of Medical Errors

Adverse event	An injury or complication caused by medical management that prolongs hospital stay or produces lasting disability or death (7, 67, 68).*
Preventable adverse event	An adverse event judged as unlikely to occur if the individuals or system involved in delivering care had followed practices regarded at the time as accepted (that is, noninvestigational) or "standard of care" (7, 67, 68).*
Error	An act of commission or omission that, based on currently available information, substantially increases the risk for an adverse event (60).†
Quality of care	The degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge (71).
Root-cause analysis	"Systematic investigation technique that uses information gathered during an intense assessment of an accident to determine the underlying reasons for the deficiencies or failures that caused the accident" (54).

* These definitions combine the essential features of several of the major studies of adverse events and their preventability.

† There is considerable controversy on how best to define "errors." Some have suggested defining them without regard to their effect on outcome (60), and others have suggested that an event should only be called an error when it causes an adverse outcome (72). The definition given here is the one preferred by the authors.

From the VA Center for Practice Management and Outcomes Research and the Quality Enhancement Research Initiative (QUERI), VA Ann Arbor Healthcare System; and University of Michigan School of Medicine and School of Public Health, Ann Arbor, Michigan.

Grant Support: Funding for the Quality Grand Rounds series is supported by the California HealthCare Foundation as part of its Quality Initiative. Dr. Hofer is supported by a Career Development Grant from Health Services Research and Development, Office of the Department of Veterans Affairs (RCD 91-303).

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Current author addresses, excerpts of the question-and-answer session, and the Appendix Table are available at www.annals.org.

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References

- Kohn L, Corrigan J, Donaldson M, eds. *To Err Is Human: Building a Safer Health System*. Institute of Medicine. Committee on Quality of Health Care in America. Washington, DC: National Academy Pr; 1999.
- Pear R. Clinton to order steps to reduce medical mistakes; a mandate for hospitals; states, in turn, will be asked to add systems to require the reporting of errors. *New York Times*. 2000:A1(N), A1(L).
- Kaufman M. Clinton seeks medical error reports; proposal to reduce mistakes includes mandatory disclosure, lawsuit shield. *Washington Post*. 2000:A02.
- Brennan TA. The Institute of Medicine report on medical errors—could it do harm? *N Engl J Med*. 2000;342:1123-5. [PMID: 10760315]
- McDonald CJ, Weiner M, Hui SL. Deaths due to medical errors are exaggerated in Institute of Medicine report. *JAMA*. 2000;284:93-5. [PMID: 10872021]
- Leape LL. Institute of Medicine medical error figures are not exaggerated. *JAMA*. 2000;284:95-7. [PMID: 10872022]
- Brennan TA, Leape LL, Laird NM, Hebert L, Localio AR, Lawthers AG, et al. Incidence of adverse events and negligence in hospitalized patients. Results of the Harvard Medical Practice Study I. *N Engl J Med*. 1991;324:370-6. [PMID: 1987460]
- Dubois RW, Rogers WH, Moxley JH 3rd, Draper D, Brook RH. Hospital inpatient mortality. Is it a predictor of quality? *N Engl J Med*. 1987;317:1674-80. [PMID: 3683509]
- Thomas EJ, Orav EJ, Brennan TA. Hospital ownership and preventable adverse events. *J Gen Intern Med*. 2000;15:211-9. [PMID: 10759995]
- Hofer TP, Bernstein SJ, DeMonner S, Hayward RA. Discussion between reviewers does not improve reliability of peer review of hospital quality. *Med Care*. 2000;38:152-61. [PMID: 10659689]
- Hayward RA, Hofer TP. Estimating hospital deaths due to medical errors: preventability is in the eye of the reviewer. *JAMA*. 2001;286:415-20. [PMID: 11466119]
- Bates DW. Unexpected hypoglycemia in a critically ill patient. *Ann Intern Med*. 2002;137:110-6. [PMID: 12118966]
- Chassin MR, Becher EC. The wrong patient. *Ann Intern Med*. 2002;136:826-33. [PMID: 12044131]
- Rex JH, Turnbull JE, Allen SJ, Vande Voorde K, Luther K. Systematic root cause analysis of adverse drug events in a tertiary referral hospital. *Jt Comm J Qual Improv*. 2000;26:563-75. [PMID: 11042820]
- Elmore JG, Wells CK, Lee CH, Howard DH, Feinstein AR. Variability in radiologists' interpretations of mammograms. *N Engl J Med*. 1994;331:1493-9. [PMID: 7969300]
- Jarvik JG, Haynor DR, Koepsell TD, Bronstein A, Ashley D, Deyo RA. Interreader reliability for a new classification of lumbar disk disease. *Acad Radiol*. 1996;3:537-44. [PMID: 8796714]
- Robinson PJ. Radiology's Achilles' heel: error and variation in the interpretation of the Röntgen image. *Br J Radiol*. 1997;70:1085-98. [PMID: 9536897]
- Lal NR, Murray UM, Eldevik OP, Desmond JS. Clinical consequences of misinterpretations of neuroradiologic CT scans by on-call radiology residents. *AJNR Am J Neuroradiol*. 2000;21:124-9. [PMID: 10669236]
- Siegle RL, Baram EM, Reuter SR, Clarke EA, Lancaster JL, McMahan CA. Rates of disagreement in imaging interpretation in a group of community hospitals. *Acad Radiol*. 1998;5:148-54. [PMID: 9522880]
- Wakeley CJ, Jones AM, Kabala JE, Prince D, Goddard PR. Audit of the value of double reading magnetic resonance imaging films. *Br J Radiol*. 1995;68:358-60. [PMID: 7795970]
- Jaeschke R, Guyatt G, Sackett DL. Users' guides to the medical literature. III. How to use an article about a diagnostic test. A. Are the results of the study valid? Evidence-Based Medicine Working Group. *JAMA*. 1994;271:389-91. [PMID: 8283589]
- Jaeschke R, Guyatt GH, Sackett DL. Users' guides to the medical literature. III. How to use an article about a diagnostic test. B. What are the results and will they help me in caring for my patients? The Evidence-Based Medicine Working Group. *JAMA*. 1994;271:703-7. [PMID: 8309035]
- Value of the ventilation/perfusion scan in acute pulmonary embolism. Results of the prospective investigation of pulmonary embolism diagnosis (PIOPED). The PIOPED Investigators. *JAMA*. 1990;263:2753-9. [PMID: 2332918]
- Tapson VF, Carroll BA, Davidson BL, Elliott CG, Fedullo PF, Hales CA, et al. The diagnostic approach to acute venous thromboembolism. Clinical practice guideline. American Thoracic Society. *Am J Respir Crit Care Med*. 1999;160:1043-66. [PMID: 10471639]
- Stein PD, Hull RD, Saltzman HA, Pineo G. Strategy for diagnosis of patients with suspected acute pulmonary embolism. *Chest*. 1993;103:1553-9. [PMID: 8486043]
- Wells PS, Ginsberg JS, Anderson DR, Kearon C, Gent M, Turpie AG, et al. Use of a clinical model for safe management of patients with suspected pulmonary embolism. *Ann Intern Med*. 1998;129:997-1005. [PMID: 9867786]
- Rathbun SW, Raskob GE, Whitsett TL. Sensitivity and specificity of helical computed tomography in the diagnosis of pulmonary embolism: a systematic review. *Ann Intern Med*. 2000;132:227-32. [PMID: 10651604]
- Mullins MD, Becker DM, Hagspiel KD, Philbrick JT. The role of spiral volumetric computed tomography in the diagnosis of pulmonary embolism. *Arch Intern Med*. 2000;160:293-8. [PMID: 10668830]
- Diamond GA, Denton TA. Alternative perspectives on the biased foundations of medical technology assessment. *Ann Intern Med*. 1993;118:455-64. [PMID: 8439120]
- Robert G, Milne R. Positron emission tomography: establishing priorities for health technology assessment. *Health Technol Assess*. 1999;3:1-54. [PMID: 10632626]
- Ukoumunne OC, Gulliford MC, Chinn S, Sterne JA, Burney PG. Methods for evaluating area-wide and organisation-based interventions in health and health care: a systematic review. *Health Technol Assess* 1999;3:iii-92. [PMID: 10982317]
- Hillman, BJ. Government health policy and the diffusion of new medical devices. *Health Serv Res*. 1986;21:681-711. [PMID: 3818311]
- Ault M, Artal R. Upper extremity DVT: what is the risk? [Letter] *Arch Intern Med*. 1998;158:1950-2. [PMID: 9759695]
- Ellis MH, Manor Y, Witz M. Risk factors and management of patients with upper limb deep vein thrombosis. *Chest*. 2000;117:43-6. [PMID: 10631197]
- Prandoni P, Polistena P, Bernardi E, Cogo A, Casara D, Verlato F, et al. Upper-extremity deep vein thrombosis. Risk factors, diagnosis, and complications. *Arch Intern Med*. 1997;157:57-62. [PMID: 8996041]
- Kooij JD, van der Zant FM, van Beek EJ, Reekers JA. Pulmonary embolism in deep venous thrombosis of the upper extremity: more often in catheter-related thrombosis. *Neth J Med*. 1997;50:238-42. [PMID: 9232088]
- de Monyé W, van Strijen MJ, Huisman MV, Kieft GJ, Pattynama PM. Suspected pulmonary embolism: prevalence and anatomic distribution in 487 consecutive patients. *Advances in New Technologies Evaluating the Localisation of Pulmonary Embolism (ANTELOPE) Group*. *Radiology*. 2000;215:184-8. [PMID: 10751485]
- Bates DW, Leape LL, Cullen DJ, Laird N, Petersen LA, Teich JM, et al. Effect of computerized physician order entry and a team intervention on preven-

- tion of serious medication errors. *JAMA*. 1998;280:1311-6. [PMID: 9794308]
39. **Leape LL, Cullen DJ, Clapp MD, Burdick E, Demonaco HJ, Erickson JI, et al.** Pharmacist participation on physician rounds and adverse drug events in the intensive care unit. *JAMA*. 1999;282:267-70. [PMID: 10422996]
 40. **Fischhoff B.** Hindsight is not equal to foresight: the effect of outcome knowledge on judgment under uncertainty. *J Exp Psychol Hum Percept Perform*. 1975;1:288-99.
 41. **Caplan RA, Posner KL, Cheney FW.** Effect of outcome on physician judgments of appropriateness of care. *JAMA*. 1991;265:1957-60. [PMID: 2008024]
 42. **Guyatt GH, Keller JL, Jaeschke R, Rosenbloom D, Adachi JD, Newhouse MT.** The n-of-1 randomized controlled trial: clinical usefulness. Our three-year experience. *Ann Intern Med*. 1990;112:293-9. [PMID: 2297206]
 43. **Enkin MW, Jadad AR.** Using anecdotal information in evidence-based health care: heresy or necessity? *Ann Oncol*. 1998;9:963-6. [PMID: 9818068]
 44. **Hofer TP, Bernstein SJ, Hayward RA, DeMonner S.** Validating quality indicators for hospital care. *Jt Comm J Qual Improv*. 1997;23:455-67. [PMID: 9343752]
 45. **Braunwald E, Fauci AS, Kasper DL, Hauser S, Longo DL, Jameson JL, eds.** *Harrison's Principles of Internal Medicine*. 15th ed. New York: McGraw-Hill; 2001.
 46. **Goldman L, Bennett JC, eds.** *Cecil Textbook of Medicine*. 21st ed. Philadelphia: WB Saunders; 2000.
 47. **Wachter RM, Goldman L, Hollander H, eds.** *Hospital Medicine*. Philadelphia: Lippincott Williams & Wilkins; 2000.
 48. **Willison DJ, Soumerai SB, McLaughlin TJ, Gurwitz JH, Gao X, Guadagnoli E, et al.** Consultation between cardiologists and generalists in the management of acute myocardial infarction: implications for quality of care. *Arch Intern Med*. 1998;158:1778-83. [PMID: 9738607]
 49. **Donohoe MT.** Comparing generalist and specialty care: discrepancies, deficiencies, and excesses. *Arch Intern Med*. 1998;158:1596-608. [PMID: 9701093]
 50. **Lewis BN.** An essay on error. *Instructional Science*. 1981;10:237-57.
 51. **Lourens PF.** Error analysis and applications in transportation systems. *Accid Anal Prev*. 1989;21:419-26. [PMID: 2695096]
 52. **Bree RL, Kazerooni EA, Katz SJ.** Effect of mandatory radiology consultation on inpatient imaging use. A randomized controlled trial. *JAMA*. 1996;276:1595-8. [PMID: 8918858]
 53. **Maurino DE, Reason J, Johnston N, Lee R.** *Beyond Aviation Human Factors*. Brookfield, VT: Ashgate Publishing; 1999.
 54. **Spath PL, ed.** *Error Reduction in Health Care: A Systems Approach to Improving Patient Safety*. Chicago: Health Forum Inc, AHA Pr; 2000:155.
 55. **Medical Risk Management Associates, LLC.** Software facilitation of sentinel event and root cause analysis. Accessed at www.sentinel-event.com/automaterca.htm on 12 July 2002.
 56. **Mold JW, Stein HF.** The cascade effect in the clinical care of patients. *N Engl J Med*. 1986;314:512-4. [PMID: 3945278]
 57. **Potts S, Feinglass J, Lefevre F, Kadah H, Branson C, Webster J.** A quality-of-care analysis of cascade iatrogenesis in frail elderly hospital patients. *QRB Qual Rev Bull*. 1993;19:199-205. [PMID: 8378075]
 58. **Dowell AM, Hendershot DC.** No good deed goes unpunished: case studies of incidents and potential incidents caused by protective systems. *Process Safety Progress* 1997;16:132-9.
 59. **Bier V.** Illusions of safety. In Perin C, Caroll JS. *Organizational Analysis in High Hazard Production Systems: An Academy Industry Dialogue*. Final Report of a workshop funded by the National Science Foundation NSF Grant #9510883-SBR. October 1997. Accessed at <http://web.mit.edu/sts/risk/intro.html> on 12 July 2002.
 60. **Hofer TP, Kerr EM, Hayward RA.** What is an error? *Eff Clin Pract*. 2000;3:1-10.
 61. **Merboth MK, Barnason S.** Managing pain: the fifth vital sign. *Nurs Clin North Am*. 2000;35:375-83. [PMID: 10873249]
 62. **Park RE, Brook RH.** Appropriateness studies [Letter]. *N Engl J Med*. 1994;330:432; discussion 433-4. [PMID: 8284013]
 63. **Brook RH.** Appropriateness: the next frontier [Editorial]. *BMJ*. 1994;308:218-9. [PMID: 8111255]
 64. **Sturm R, Sherbourne CD.** Managed care and unmet need for mental health and substance abuse care in 1998. *Psychiatr Serv*. 2000;51:177. [PMID: 10654995]
 65. **Clark LT.** Improving compliance and increasing control of hypertension: needs of special hypertensive populations. *Am Heart J*. 1991;121:664-9. [PMID: 1989402]
 66. **Weeks WB, Bagian JP.** Developing a culture of safety in the Veterans Health Administration. *Eff Clin Pract*. 2000;3:270-6. [PMID: 11151523]
 67. **Wilson RM, Harrison BT, Gibberd RW, Hamilton JD.** An analysis of the causes of adverse events from the Quality in Australian Health Care Study. *Med J Aust*. 1999;170:411-5. [PMID: 10341771]
 68. **Thomas EJ, Brennan TA.** Incidence and types of preventable adverse events in elderly patients: population based review of medical records. *BMJ*. 2000;320:741-4. [PMID: 10720355]
 69. **Warner KE, Warner PA.** Is an ounce of prevention worth a pound of cure? Disease prevention in health care reform. *J Ambul Care Manage*. 1993;16:38-49. [PMID: 10128416]
 70. **Glasgow RE, Hiss RG, Anderson RM, Friedman NM, Hayward RA, Marrero DG, et al.** Report of the health care delivery work group: behavioral research related to the establishment of a chronic disease model for diabetes care. *Diabetes Care*. 2001;24:124-30. [PMID: 11194217]
 71. **Brook RH, Lohr KN.** Efficacy, effectiveness, variations, and quality. Boundary-crossing research. *Med Care*. 1985;23:710-22. [PMID: 3892183]
 72. **Leape LL.** Error in medicine. *JAMA*. 1994;272:1851-7. [PMID: 7503827]