In Search of Tools to Aid Logical Thinking and Communicating about Medical Decision Making

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To have real-time impact on medical decision making, decision analysts need a wide variety of tools to aid logical thinking and communication. Decision models provide a formal framework to integrate evidence and values, but they are commonly perceived as complex and difficult to understand by those unfamiliar with the methods, especially in the context of clinical decision making. The theory of constraints, introduced by Eliyahu Goldratt in the business world, provides a set of tools for logical thinking and communication that could potentially be useful in medical decision making. The author used the concept of a conflict resolution diagram to analyze the decision to perform carotid endarterectomy prior to coronary artery bypass grafting in a patient with both symptomatic coronary and asymptomatic carotid artery disease. The method enabled clinicians to visualize and analyze the issues, identify and discuss the underlying assumptions, search for the best available evidence, and use the evidence to make a well-founded decision. The method also facilitated communication among those involved in the care of the patient. Techniques from fields other than decision analysis can potentially expand the repertoire of tools available to support medical decision making and to facilitate communication in decision consults. ***Key words:*** medical decision making; theory of constraints; communication. **(Med Decis Making 2001;21:267–277)**

The Story

Being a vascular radiologist, I regularly attend the vascular conference at the university hospital. It's an interesting conference: The professor of surgery loves academic discussions, and each case receives much attention. The conference usually takes 3 hours. The clinical fellows complain, of course, and it certainly keeps me from my regular work of writing proposals and papers. But it's one of the few conferences that I attend where there is a real discussion of the risks and benefits, and the costs, of the management options. Even patient preferences are sometimes (albeit rarely) considered.

But a few weeks ago I started getting fed up with the whole thing. The discussions always seem to go along the same lines: Dr. Smith says that he feels that treatment X is the right thing to do because he recently read a paper that mentioned that X was beneficial; Dr. Johnson counters that X has a substantial risk associated with it, as was shown in the paper published last year in the world's highest ranking journal in the field, and should therefore not be considered; and Dr. Gray says that given the current limited budget in the department, maybe we should consider a less expensive alternative or no treatment at all. After talking around in circles for about 10 to 15 minutes, with each doctor reiterating his or her opinion and new facts popping up from time to time, the professor of vascular surgery finally stops the discussion, realizing that his fellows are getting irritated because they have work to do. Practical chores are waiting. And so the professor concludes, "Okay. So it seems we should be doing treatment X." About 40% of those involved in the decision-making process nod their heads in agreement, another 40% start bringing up objections (which get stifled quickly by the fellows who *really* don't want an encore), and the remaining 20% of those involved are either too tired or too flabbergasted to respond or are optimizing another goal in life, namely, job security.

Does this sound familiar?

So I decided I needed to do something that would make the conference more productive, possibly

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more efficient, and of more interest to myself. The first thing I did was to copy a set of papers that we commonly refer to during the conference (but never seem to have available), and at the next conference I had some evidence available to support or counter the arguments made. The clinical fellow in vascular surgery caught onto the idea real fast! The next week, she called me in advance of the conference to explain a decision problem she was having with one of her patients:

VS: I have a patient whom I'd like to present at the next vascular conference, and I was wondering if you could get some evidence together to make the discussion more focused.
MGMH: Sure. Tell me about the case.
VS: Well, it concerns a 70-year-old gentleman with coronary artery disease who also has an asymptomatic carotid artery stenosis. We're wondering whether we should perform a carotid endarterectomy prior to coronary artery bypass surgery, perform carotid endarterectomy at the same time as bypass surgery, or perhaps not perform it at all.

I decide that doing a formal decision analysis for the problem would be the best way to go. But I have 2 working days to go before the conference, the weekend is already filled with social and family outings, and I have a book chapter and a proposal I need to finish by next week, not to mention all the papers that need to be revised, the imaging studies that need to be supervised and reported, and the scheduled meetings that need to be prepared and attended. Do a formal decision analysis as well? That would imply trying to implement a decision consult service (without the help of fellows) and with a turnaround time of 2 days—a daunting task that others have found extremely challenging.[1–3] And when the decision analysis is done, how do I explain to the clinicians what I've done and what it means? Will they understand, and trust, the model? Will they apply the results?

Isn't there a simpler way?

First, I search for a guideline in the literature. The American Heart Association published a guideline for carotid endarterectomy in 1995.[4] I search for the relevant section and to my dismay, it reads "the optimal strategy for management of patients with combined coronary and carotid disease will be established only by a well-designed prospective randomized trial." Guidelines can be helpful, but how often has this happened to you? Too often? It's frustrating. Not only that, the guideline is from 1995, and we've now entered the next millennium. Is it still applicable? It occurs to me that based on this guideline, I can make the decision by starting a randomized controlled trial (RCT) immediately with this patient; that is, why don't I just toss a coin and be done with it? The answer is straightforward: I want to make a good decision for this patient justified by the best available evidence.

Maybe it is wiser to first search for an RCT that may provide an answer to the problem. A large published trial that may be helpful randomized patients with asymptomatic carotid artery stenosis to carotid endarterectomy plus medical treatment versus medical treatment only and found a 5-year aggregate risk for ipsilateral stroke and any perioperative stroke or death of 5.1% for surgical patients and 11.0% for patients treated medically (aggregate risk reduction of 53%; 95% confidence interval [CI] = 22%–72%).[5] But the report states very clearly that these were patients in good general health and that the perioperative morbidity and mortality was less than 3%. Our patient and our setting do not seem to fit this description.

Next, I search for a decision analysis that addresses the problem. Cronenwett and others[6] published an analysis in 1997 that addressed the cost-effectiveness of carotid endarterectomy in asymptomatic patients. Great! This sounds like it may be helpful. But again I am disappointed. The analysis does not address the decision I have to make for this patient in our setting. The authors do not explicitly consider patients with coronary artery disease (CAD), the inputs they use are different from what probably applies in our setting, and issues relevant to this case are not considered.

I begin to wonder what the issues are (Figure 1). The primary decision we have to make is whether carotid endarterectomy should be performed prior to coronary artery bypass grafting (CABG) or not performed at all. We should keep in mind that an alternative would be to perform the operations simultaneously under the same anesthesia, but then we are still faced with the problem of which operation should be performed first, probably the endarterectomy. I make a conflict resolution diagram (or "evaporating cloud" as Eliyahu Goldratt calls it) (Figure 1).[7,8]

Presumably, the overall goal of health care is to maximize life expectancy and quality of life at an

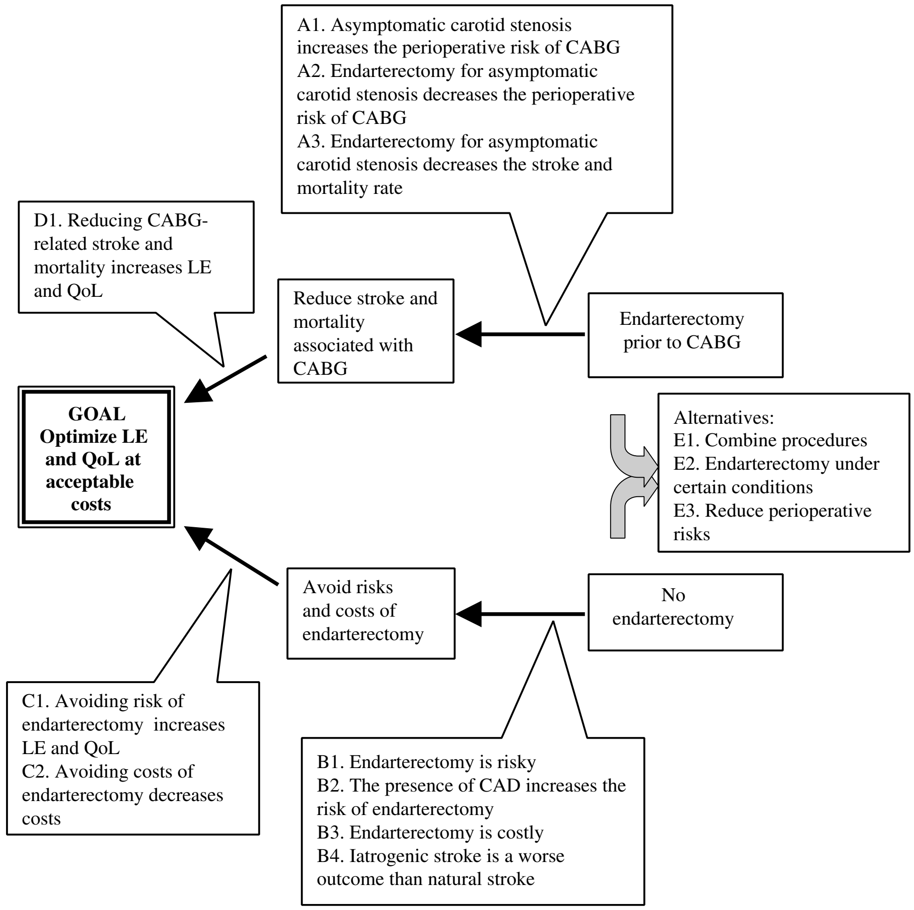

FIGURE 1. Conflict resolution diagram ("evaporating cloud") illustrating the decisional conflict between performing carotid endarterectomy prior to coronary artery bypass grafting (CABG) versus not performing endarterectomy in a patient with both coronary artery disease (CAD) and asymptomatic carotid artery stenosis (LE = life expectancy; QoL = quality of life).

acceptable cost to society. This is the goal as stated from a societal perspective, and depending on the decision maker's perspective, the objectives may be different. But let's assume that we want to optimize health care outcomes at a reasonable cost. Then why do we think we should perform endarterectomy prior to CABG in order to achieve our goal? Because by performing an endarterectomy we hope to reduce the perioperative stroke and mortality rate associated with CABG in a patient with asymptomatic carotid stenosis. At the same time, we would reduce the long-term stroke rate associated with carotid artery stenosis. And why do we think we should not perform a carotid endarterectomy? Because we want to avoid the risks and costs of endarterectomy, especially since the patient is asymptomatic.

The diagram represents a closed circle, a conflict. Our goal is clear, but on the one hand we believe we need to perform endarterectomy prior to CABG to achieve our goal and on the other hand we believe we should not perform endarterectomy to achieve our goal. No wonder there is tension! There is a decisional conflict, and the tension will persist until we are able to resolve the conflict.

So what are the assumptions underlying the arrows that lead from the option "perform endarterectomy prior to CABG" to our goal and underlying the arrows that lead from the option "do not perform endarterectomy" to our goal? Can we make these assumptions explicit? Can we find evidence to support or weaken these assumptions? Are there hidden fears underlying the arrows that need to be acknowledged and discussed? If we can weaken the assumptions (and mitigate the fears) underlying one of the arrows, the closed circle representing the conflict will be broken, and it will be clear what the decision should be. So let's consider the underlying assumptions and challenge them one by one.

A1. *Asymptomatic carotid artery stenosis increases the perioperative risk of CABG*. Two case series (n = 94 and n = 46) do not demonstrate an increase in risk.[9,10] Because both are fairly small case series, this evidence weakens the assumption but does not refute it.

A2. *Carotid endarterectomy for asymptomatic carotid artery stenosis decreases the stroke and mortality rate associated with CABG*. There is no evidence that performing carotid endarterectomy prior to CABG decreases the perioperative risk of CABG.[4]

A3. *Carotid endarterectomy for asymptomatic carotid artery stenosis decreases the stroke and mortality rate compared with medical therapy*. A published meta-analysis based on RCTs,[11] including the large RCT by the National Health and Medical Research Council[5] mentioned earlier, demonstrated that the combined carotid endarterectomy perioperative stroke or death rate plus long-term ipsilateral stroke rate was 4.4% in the endarterectomy group and 6.4% in the medical group. The odds ratio was 0.62 (95% CI = 0.44–0.86) and the number needed to treat was 50 during 3.1 years of follow-up. There is a caveat: These results were achieved in patients otherwise in good health operated on in selected centers.

B1. *Carotid endarterectomy is risky*. The published meta-analysis based on RCTs of endarterectomy for asymptomatic carotid artery stenosis demonstrated a perioperative stroke or death rate of 2.6%.[11] This was supported by a separate analysis that demonstrated a perioperative stroke or death rate of 3% (2% to 4%) associated with endarterectomy for asymptomatic carotid artery stenosis and 5% when performed for symptomatic carotid artery stenosis.[12] Keep in my mind that our patient and our setting may be very different.

B2. *The presence of CAD increases the risk of carotid endarterectomy*. Based on the North American Symptomatic Carotid Endarterectomy Trial (NASCET) (n = 1415 symptomatic patients), the risk of medical complications associated with endarterectomy was 1.6 times as high in patients with a history of CAD as in patients without CAD,[13] which applies to our patient.

B3. *Carotid endarterectomy is costly*. Angiography plus carotid endarterectomy costs approximately $10,000.[6,13]

C1. *Avoiding the risk of carotid endarterectomy increases life expectancy and quality of life*. Avoiding carotid endarterectomy would avoid the perioperative combined stroke and death risk. Avoiding the perioperative risk of carotid endarterectomy increases life expectancy and quality of life. The meta-analysis, however, suggests that endarterectomy decreases the long-term ipsilateral stroke rate, which outweighs the risk of the procedure but only if the perioperative risk is low (see assumption A3).

C2. *Avoiding the costs of carotid endarterectomy decreases overall costs*. Avoiding carotid endarterectomy will reduce the short-term costs. The cost-effectiveness analysis, however, suggests that the cost of angiography plus carotid endarterectomy ($10,000) is justified by the cost-savings in the long term, the cost of a stroke being $34,000 in the year following the stroke and $18,000 per year thereafter.[6] The incremental cost-effectiveness ratio of carotid endarterectomy in asymptomatic patients was less than $8000 per quality-adjusted life year, which is favorable. The main caveat is that the baseline assumption in the analysis for the perioperative risk was 2.3%, which does not apply to our patient, who has CAD.

D1. *Reducing CABG-related stroke and mortality increases life expectancy and quality of life*. This seems to be a reasonable assumption. Some surgeons, however, have the subjective opinion that even if stroke does not occur, quality of life may be negatively affected by nonspecific neurological deficits due to ischemia occurring at the time of CABG. There is no good quantitative evidence to support this argument, however.

Alternative options can be considered:

E1. *Combine carotid endarterectomy and CABG*. A recent case series (n = 470) in which CABG and carotid endarterectomy were combined demonstrated a combined mortality and stroke rate of 3.4%.[14] Fifty-six case series of combined carotid endarterectomy and CABG published between 1972 and 1992 were pooled in a meta-analysis, which indicated a cerebrovascular accident (CVA) rate of 6.2%, a myocardial infarction (MI) rate of 4.7%, and a death rate of 5.6%.[4] Staged procedures incurred the following risks: endarterectomy-CABG was associated with a 9.4% death rate, a 5.3% CVA rate, and an 11% MI rate; and staged CABG-endarterectomy was associated with a 10% CVA rate, a 2.7% MI rate, and a 3.6% death rate.[4]

E2. *Carotid endarterectomy under certain conditions*. Both the AHA guideline and a more recent editorial suggest that carotid endarterectomy for asymptomatic patients should only be performed if the perioperative risk of stroke and death is less than 3%.[4,15]

E3. *Reduce perioperative risks*. A decision analysis suggests that the perioperative risks can be reduced using noninvasive imaging tests (such as duplex ultrasound and magnetic resonance angiography [MRA]) instead of catheterization with contrast X-ray angiography.[16]

At the vascular conference, I present the conflict resolution diagram and lead the audience through the available evidence. The discussion focuses on the following:

1. We do not have conclusive evidence that the asymptomatic carotid artery stenosis will actually increase the risk of CABG and that performing endarterectomy will decrease the perioperative risk of CABG; that is, we have not found conclusive evidence to support assumptions A1 and A2.
2. We discuss whether the perioperative risk of carotid endarterectomy in this asymptomatic patient with CAD in our setting is justified by the increase in life expectancy and quality of life; that is, we reconsider assumptions A3 and C1 in the context of our own specific setting. We also consider whether the cost of carotid endarterectomy is worth the downstream cost-savings, but the risks play a more important role than the costs in the discussion.
3. We consider how we could potentially reduce the perioperative risks (E3).

I present a sensitivity analysis from the cost-effectiveness paper that addresses the change in cost-effectiveness with a varying perioperative stroke or death rate for 3 age groups—55-, 65-, and 75-year-olds—and discuss how we can apply these results to our patient:

MGMH: So tell me, what is the endarterectomy perioperative stroke and death rate in our hospital?

VS: I recently reviewed our results. Among 61 patients operated over the past 2 years, 1 died and 2 had a stroke.

MGMH: Okay. So overall the perioperative risk is 3/61, or 4.9%. I assume these were symptomatic patients. This rate corresponds closely with the published rate of 5.2% by Rothwell in *Stroke* 1996. He found that one could expect a lower rate in asymptomatic patients of 3.4%, which corresponds to an odds ratio of 0.61. So overall for our asymptomatic patients we can expect the perioperative risk to be approximately 60% of 4.9%, or about 3%. For this particular patient the risk will, however, be higher because of the associated coronary artery disease, which increases the risk by 1.6 times based on the NASCET data published in *Stroke* 1999. Thus, based on what you just told me of the results here in our setting combined with the evidence from the literature, I would estimate the perioperative risk for our patient to be approximately 4.8%.

VS: Except that in our hands the complication rate among asymptomatic patients was higher. Among the 61 patients I mentioned, 4 were actually asymptomatic, and 1 asymptomatic patient had a stroke as a result of the operation. I personally didn't perform the operation, but still. Who says it won't happen to me? A probability of 25%. Ugh. If there is something that I hate in my job, it's causing a stroke in an asymptomatic patient.

MGMH: The fallacy of small numbers and a stroke of bad luck? I get the impression that the particular case is very prominent in your mind and has biased your thinking in subsequent decision making. Have you considered that if you don't operate, you may cause a stroke by not having done anything?

VS: But that's different! A stroke caused now by something I do is a different case from a stroke caused later by the natural course of events. Not only for me, but also for the patient.

MGMH: If I understand you correctly, there are 2 things that concern you. First, both you and the patient value an iatrogenic stroke as worse than a natural stroke (Figure 1, B4).

VS: You bet! If someone develops a complication from an operation performed for symptoms, it's not as bad. But I really have feelings of regret when a complication occurs in an asymptomatic patient.

MGMH: I understand. Someone is apparently healthy and because of something you have done, they have an event and are subsequently disabled for the rest of their life. This subjective value is very difficult to incorporate explicitly into our decision-making process. But it clearly biases us against performing endarterectomy. It's not specific to this problem, mind you. The same applies, for example, when you operate on a patient with an asymptomatic abdominal aortic aneurysm. Let's keep this issue of potential regret in mind but now move our attention to the 2nd issue you brought up: An event occurring now is valued as far worse than if that same event occurs in the future. This is because an event now will cause disability to the patient for the remaining years of his life. We can tackle this by calculating life expectancy and adjusting for the quality of life during each year of that remaining life expectancy. By doing that, we take into account when the event occurs and how long the patient lives with the disability. That's what the decision analysts have done in this paper we're discussing.

VS: Yes, I understand that, but even so disability in the future can be expected and of less concern than disability now. For that matter, an extra year of life 10 years from now seems somewhat irrelevant compared to being alive and well now.

MGMH: You mean that the value of a life year, or quality-adjusted life year for that matter, in the future has less value than a quality-adjusted life year now?

VS: [nods]

MGMH: We can actually address that by discounting future years, similar to discounting costs. That is, we use a formula that weighs years in the future less than immediate years. In the analysis that I'm presenting, both costs and health benefits were discounted at 5% per year. You can question whether 5% is the correct number, but at least it adjusts the estimate for your concern. And they examined the effect of smaller and larger discount rates in a sensitivity analysis.

VS: Okay. Let's look at the results.

The sensitivity analysis presented in the article by Cronenwett and others[6] demonstrates that for a 65-year-old, the incremental cost-effectiveness ratio of endarterectomy compared with medical therapy remains well within accepted cost-effectiveness values for a perioperative risk (stroke or death) of less than 4.8%. For 75-year-olds, the threshold perioperative risk is 1%. Because our patient is 70 years old, the threshold value is somewhere in between these 2 values, probably close to 3%. Our estimate for the perioperative risk for this patient, taking into account that he is asymptomatic with respect to his carotid disease but has CAD, was on the order of 4.8%, well above the threshold value of 3%. So we should consider endarterectomy only if we can reduce this perioperative risk substantially.

By combining carotid endarterectomy and CABG, we can reduce the combined risk of the 2 procedures. But to justify the endarterectomy, the combined risk should not substantially exceed the risk of CABG alone. A recent case series of 470 patients in which CABG and carotid endarterectomy were combined (E1) demonstrated a combined mortality and stroke rate of 3.4%.[14] The reported mortality and stroke rate seems exceptionally low, and we doubt whether we can replicate such good results. The 56 case series of combined carotid endarterectomy and CABG that were pooled in a meta-analysis indicated a reduction by 40% in the risk of CVAs with simultaneous endarterectomy and CABG procedures compared with staged CABG-endarterectomy, but this reduction was associated with a substantial increase in the death rate.[4] Simultaneous endarterectomy and CABG procedures reduced the death rate but increased the CVA rate compared with staged endarterectomy-CABG. Replacing catheterization angiography with magnetic resonance angiography (MRA) will reduce the perioperative risk of carotid endarterectomy, but the risk would still be about 3.5% to 4.0%.[16]

Discussion

The bottom line of the presentation and discussion at the vascular conference was that performing carotid endarterectomy in an asymptomatic patient with CAD is not warranted based on the evidence currently available. The conflict resolution diagram highlighted that there is no conclusive evidence to support our assumptions that asymptomatic carotid artery stenosis will increase the risk of CABG and that performing endarterectomy prior to CABG will decrease this risk. The visual aid helped refocus the discussion, which first revolved around the benefits of endarterectomy in reducing the perioperative risk of CABG but then addressed whether endarterectomy for asymptomatic carotid artery stenosis is justified in general and specifically in patients with CAD. Having refocused the discussion, we could then apply the results of a large RCT, a meta-analysis, and a cost-effectiveness analysis to support the argument that endarterectomy for asymptomatic patients infers only a small benefit and does so only if the perioperative risk is very low. Because the perioperative risk can be expected to be high in our elderly patient with CAD, it seemed fairly straightforward to conclude that endarterectomy would not be justified. The decision was furthermore consistent with our policy of not routinely performing carotid endarterectomy in asymptomatic patients. However, in the light of the evidence, we may want to reconsider our policy for patients with asymptomatic carotid artery stenosis who are otherwise in good health, especially if we can replace catheterization angiography with a noninvasive imaging test such as MRA.

The above story describes the use of one of the tools introduced by Goldratt in his books *The Goal*[7] and *It's Not Luck*.[8] Goldratt was a physicist who wrote several books on management in business. He introduced various tools for logical thinking and bundled the concepts under the term *theory of constraints*. His main message was that we can solve problems through logical thinking, and he described several tools to help us. The tool we have used here is the evaporating cloud, which may also be called a conflict resolution diagram.

The 1st step in setting up a conflict resolution diagram is to identify the conflict. In the example, we discussed a decisional conflict between performing or not performing a carotid endarterectomy in a patient with symptomatic coronary and asymptomatic carotid artery disease. In the context of decision making, the choice of strategy can be considered the decisional conflict.

Next, we need to define our goals. We need to distinguish the global overall goal of health care from goals set by individual decision makers involved in the health care system. Different perspectives may very well lead to different definitions of "the goal," and initiating a discussion about the goal can uncover the reason for differences in opinion about the optimal decision. In medical decisions from the societal perspective, the goal is usually to maximize quality and length of life at an affordable monetary cost, in other words, maximize net health benefits.[17] From the patient's perspective, the goal may, for example, be to maximize quality of life. The vascular surgeons may focus on minimizing the perioperative stroke and death rate to minimize the chance of liability and regret. By explicitly discussing the goal, differences can be brought out into the open and a shared global goal can be formulated. Furthermore, during the ensuing discussion, differences in opinion about the evidence can be considered in the light of differences in goals.

The 3rd step is to identify the prerequisites to the goal. These prerequisites are the link between the decisional conflict and the goal. In the story, for example, we said that to maximize life expectancy and quality of life, we needed to reduce the risk associated with CABG, which led to the perceived need to perform endarterectomy prior to CABG. On the other hand, we said it was necessary to avoid the risk of endarterectomy to achieve our goal, which led to the perceived need of not performing endarterectomy. Thus, we had a decisional conflict between 2 courses of action, both of which were perceived as being necessary to achieve our goal, which clearly leads to tension. Note that the conflict resolution diagram represents a closed circle. As long as the conflict remains unresolved, tension will persist.

The 4th step is to make the underlying assumptions and hidden fears explicit and to discuss them. The underlying assumptions in the story concerned the mortality and morbidity risks, the benefits, and the costs associated with the various treatment options. For each assumption, we tried to find the appropriate best available evidence from the literature that could be used either to strengthen or weaken the argument made. By

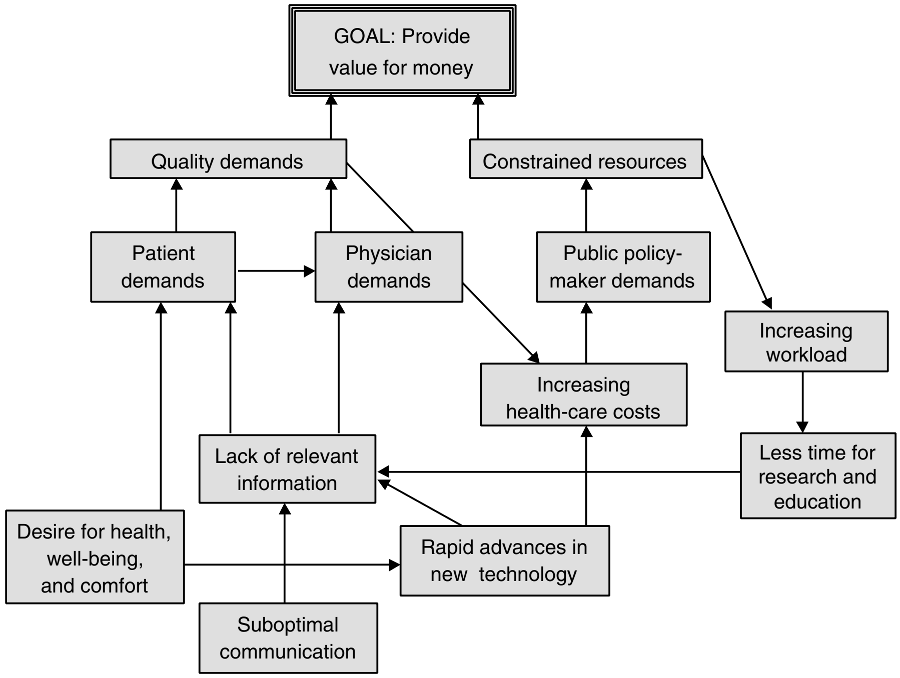

FIGURE 2. Current reality tree illustrating a simplified model of some of the current problems in health care. The current reality tree suggests that suboptimal communication together with our fundamental desire for health, well-being, and comfort underlie many of the problems in health care. Note the negative feedback loop going from patient and physician demands to quality demands; through increasing health care costs, public policy maker demands, constrained resources, increasing workload, less time for research and education, and lack of relevant information; and back to patient and physician quality demands.

analyzing the problem explicitly and systematically, we can uncover hidden assumptions and fears such as the worry of the vascular surgeon of inducing a stroke. Once the assumptions and fears are discussed and considered in the light of the best available evidence, the decisional conflict can generally be resolved and the optimal decision will be clear. Visually, we are breaking one of the arrows in the diagram: Only 1 of the arrows of the closed circle needs to be broken to resolve the decisional conflict.

By going step by step through the conflict resolution diagram, we also uncovered and discussed an underlying value judgment of the vascular surgeon that was driving her thinking: the fact that she values an iatrogenic event as far worse than the same event occurring as part of the natural history. By making such value judgments explicit and discussing them, we can deal with them more effectively.

The tools for problem solving using logical thinking described by Goldratt were originally described for production management, marketing, and project management.[7,8,18] Apart from the evaporating cloud or conflict resolution diagram described above, a number of other tools were described by Goldratt, including the current reality tree, the future reality tree, and the balance sheet.

The current reality tree, or model of the symptoms, is a representation of undesirable effects, or symptoms, in a particular situation. To set up the model, we start by listing some of the undesirable effects we need to deal with. Then, we ask why each of the undesirable effects is there and how the effects are interconnected. We work backward until we identify the underlying problem (or a limited set of problems) that produces the whole set of undesirable effects. For example, the current reality tree presented in Figure 2 illustrates an extremely simplified model of some of the current problems in health care and suggests that suboptimal communication together with our fundamental desire for health, well-being, and comfort underlie many of the problems in health care. The underlying problem may also be a conflict, real or perceived. This may be an inner conflict of the decision maker, a conflict that many people have to deal with, or a conflict between people who appear to have opposing interests. The underlying conflict commonly represents a generic conflict, such as the current conflict in health care between cost and quality. We can often identify

Table 1 • A Balance Sheet to Explicitly Consider and Compare the Evidence Supporting the Decision Options "No Carotid Endarterectomy" and "Carotid Endarterectomy prior to Coronary Artery Bypass Grafting" in a Patient with Symptomatic Coronary Artery Disease and Asymptomatic Carotid Artery Stenosis

Outcome	No Carotid Endarterectomy	Carotid Endarterectomy prior to Coronary Artery Bypass Grafting
Short-term stroke and mortality rate	Two case series (n = 94 and n = 46) *do not* demonstrate an increase in risk of CABG in the presence of an asymptomatic carotid stenosis.[9,10] (A1) Endarterectomy for asymptomatic carotid artery stenosis was associated with a perioperative stroke or death rate of 3% (2% to 4%).[11,12] (B1) Risk of medical complications associated with endarterectomy was 1.6 times as likely in patients with CAD as in patients without CAD.[13] (B2)	
Long-term stroke and mortality rate		Combined ipsilateral stroke plus perioperative stroke or death rate was 4.4% in the endarterectomy group and 6.4% in the medical group, but only if perioperative risk is low; the odds ratio was 0.62 (95% confidence interval = 0.44-0.86) and the number needed to treat was 50 with a 3.1-year follow-up.[11] (A3)
Quality of life	Quality of life with stroke is about 0.40.[6] (C1)	Quality of life with stroke is about 0.40.[6] (D1)
Regret	Iatrogenic stroke is a worse outcome than natural stroke (subjective value). (B4)	
Short-term costs	Angiography plus endarterectomy costs approximately $10,000.[6] (B3)	
Long-term costs	Cost of stroke is $34,000 in the year following the stroke and $18,000 per year thereafter.[6] (B1 + B2 + C2)	Cost of stroke is $34,000 in the year following the stroke and $18,000 per year thereafter.[6] (A3 + C2)

Note: CABG = coronary artery bypass grafting; CAD = coronary artery disease.

feedback loops within the current reality tree. These may have either a positive or negative effect on the overall goal. For example, in Figure 2 there is a negative feedback loop going from patient and physician demands to quality demands; through increasing health care costs, public policy maker demands, constrained resources, increasing workload, less time for research and education, and lack of relevant information; and back to patient and physician quality demands. Negative feedback loops usually indicate the presence of some underlying conflict, such as the conflict between quality of care and cost of care, that needs to be addressed.

Tackling the underlying conflict using a conflict resolution diagram can help us identify a solution to the undesired situation. These conflicts represent the constraint in the system. We need to recognize that the underlying conflicts are leading to the undesirable effects and that as long as those conflicts are unresolved, undesirable effects will remain present. Solving one undesirable effect (or symptom) will only cause another to show up somewhere else. The direction of the solution to the undesirable effects is in the resolution of the underlying conflict. For example, the tension between keeping health care affordable versus providing high-quality state-of-the-art care will persist until we can either weaken the assumptions underlying the conflict or find a balance between cost and quality.

The future reality tree, or scenario analysis, can help us examine how the identified solution will affect the symptoms in the current reality tree. In other words, we need to use the current reality tree as a model of the current situation and then examine how implementing the solution affects the flow of the process, the undesirable effects, and the overall goal. We need to examine the negative side effects of the solution and think through how we can avoid each of them. When we examine and discuss the effects of the implementation of a solution in a scenario analysis, we find ways to overcome the obstacles to implementation.

Another useful tool for making decisions described by Goldratt is a listing of "pluses and minuses."[8] This is the same as a balance sheet (Table 1), also known as a consequence table, which has been described by others in the context of business management and personal decision making[19] and has been described in the evidence-based medicine literature.[5] A balance sheet can be very helpful in structuring and formulating the consequences of all alternatives considering each of the objectives. Most of us probably use this tool to some degree or another both for medical decisions and decisions concerning our own lives. In the setting of medical decisions, a balance sheet tabulates all the options versus the objectives we wish to optimize such as risks, benefits, patient preferences, and costs. This visual aid (Table 1) helps bring together all the important information in a concise framework and is a systematic approach to decision making. Hammond and others[19] described methods for making trade-offs using a balance sheet that can be very helpful in the decision-making process.

Conflict resolution diagrams, current reality trees, balance sheets, and decision models all aid decision making. They are analytical tools and at the same time visual aids that help us think through problems from various angles and lead us systematically through all the aspects of a decision problem. At the same time, they are holistic system-thinking tools in that they provide a broad perspective, give an overview of the problem, and demonstrate the interconnection of the pieces. The basic underlying notions are the same, that is, systematic logical thinking, looking at all aspects of the problem, making assumptions explicit, gathering information, and integrating evidence and values in one framework to aid decision making. In this sense, the theory of constraints for medical decision making is not an alternative to decision analysis and not a new theoretical framework. Instead, the techniques from the theory of constraints are adjuncts to the tools that we already have at our disposal. They provide another way of looking at a problem and visually representing decisions. Most important, they facilitate communication.

The distinction between these tools is that whereas decision models are used to quantitatively integrate information and estimate outcomes such as quality-adjusted life expectancy and lifetime costs, conflict resolution diagrams and balance sheets are used to qualitatively integrate the same information. In the example described, the use of a conflict resolution diagram helped refocus the discussion, made the underlying assumptions explicit even without estimates of probabilities and values, and uncovered the vascular surgeon's hidden fear and value judgment concerning iatrogenic strokes. The conflict resolution diagram provided the same insights as those gained from a formal decision analysis but used a less complex tool. Examining the problem from various viewpoints in multiple ways and considering all the different aspects and information pertinent to the decision often suggests what the optimal decision is; the calculations commonly serve only to support that insight formally. Sometimes only a limited calculation is necessary. Going through a formal decision analysis is really only required when a qualitative assessment suggests that a quantitative trade-off of competing objectives is desired. Finally, using visual aids that are somewhat informal (rather than a formal decision analysis) can ease understanding and acceptance of the analyses we perform and facilitate communication with people not familiar with decision models.

Why are these tools helpful? Don't we as clinicians think in terms of risks and benefits when making medical decisions? Yes, we probably do. But the difference is that with these tools, we put our assumptions and the evidence on paper. We lay it out, explicitly. The main problem with making decisions implicitly in our heads is that a human brain can only grasp 7 facts (plus or minus 2) at any one time,[20] even though we all think we are the exception. So we tend to hone in on a particular piece of the problem and can't broaden our view at the same time to consider the other pieces. We focus, for example, first on the assumptions A in the upper part of Figure 1. Ten minutes later, we move to assumptions B in the lower part of the figure, and then to C and D and E. But by the time we've arrived at E, we've forgotten what was said (or thought) at the beginning, and before long we're back to arguing about assumptions A. Without a visual aid, we tend to go around in circles and get stuck in our thinking, our discussions, and our arguments. Or we focus on optimizing one tiny piece and forget to think about whether optimizing that piece serves our overall goal. For example, we may try to avoid immediate costs and forget that the downstream cost-savings may be far more important. Visual aids allow us take a broad perspective. It is like "going to the balcony" and trying to get a general overview of what's happening. Such tools help us to think through, and discuss, the problem from various perspectives and, hence, think and communicate in a systematic logical way. It's like playing chess on a board instead of in your head: On the board, it is so much easier to see what happens!

Finally, if the medical decision making community is to have real-time impact on decision making, we will need to develop tools to aid logical thinking and to communicate effectively with our audience. Decision models provide a formal framework to integrate evidence and values, but they are commonly perceived as complex and difficult to understand by those unfamiliar with the methods. Furthermore, a formal decision analysis is not always necessary for a well-founded decision. I suggest we expand our repertoire of tools to aid logical thinking about medical decisions and especially to facilitate communication with those we are trying to support in their decision making.

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