Making Decisions About Admitting Patients to Coronary Care Units

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Over one half of the patients admitted to US hospitals with chest pain ultimately fail to demonstrate acute cardiac ischemia.[1] Projected over the 1½ million coronary care unit (CCU) admissions experienced annually, this represents a substantial strain on a relatively scarce resource. Yet how can we reduce the large number of "false-positive" admissions without mistakenly dismissing patients who truly have acute ischemic heart disease? Several authors have developed clinical decision aids to provide guidance in these situations. Goldman and colleagues used recursive partitioning to create the Goldman chest pain protocol[2]; this instrument used nine clinical and two electrocardiographic variables to stratify patients risk. Lee et al[3] studied this instrument prospectively and unfortunately found no significant changes in hospital and coronary care unit admission rates.[3] They also found that average total costs and lengths of stay demonstrated no significant differences between the control and intervention periods.

Additional quantitative decision support systems have appeared in the literature. Tierney and associates[4] have reported a multivariate model that utilized the Regenstrief Institute's computerized medical record system; although the system performed well, the instrument has not undergone trials in different institutional environments. Aase et al[5] developed a system that uses historical variables in a Bayesian probability model, and Dilger and colleagues[6] have similarly used historical, laboratory, and ECG variables in a logistic regression system. These two instruments, like Tierney's tool, have not undergone prospective testing in different representative clinical environments.

In this issue of the *Journal*, Green and Mehr[7] report an intervention trial using the acute ischemic Heart Disease Predictive Instrument (HDPI) developed by Pozen and colleagues.[8,9] The HDPI uses seven clinical and ECG variables to provide to the clinician a number between 0 and 1, which represents the probability that a patient experiencing chest pain actually harbors acute cardiac ischemia.[10]

In spite of this good performance, subsequent studies of the HDPI (as noted by Green and Mehr) have demonstrated mixed results. The developers of the original instrument have themselves recognized some of the tool's limitations: as originally conceived, the instrument required use of a programmable calculator, and at least one of the ECG variables (ST-segment "straightening") represented a fairly subjective assessment.[1] Users can circumvent the need for access to a programmable calculator or computer by using cards that present the scoring system in an easy-to-use tabular format (the system used by Green and Mehr). The instrument's developers have obviated the second shortcoming by revising the ECG criteria and incorporating the instrument into computers embedded in the electrocardiograph itself.[10,11]

Contrary to previous mixed results, Green and Mehr's study suggests that the HDPI indeed improved relatively inexperienced clinicians' ability to appropriately identify patients with and without acute cardiac ischemia. Surprisingly, this improvement appears to have occurred as the result of a fairly limited initial educational intervention: presentation at a departmental conference.

As they note in their paper, such efforts frequently disappoint us in our efforts to effect substantial sustained improvement in significant clinical outcomes. However, was this really a simple intervention? The authors indicate that the initial presentation occurred in a fairly informal setting and involved a small audience. Additionally, the authors had the opportunity to provide informal feedback over a number of months to participants regarding their management of chest pain.

We know from postgraduate educational experience that the typical large group presentation to an unprepared audience has disappointing long-term impact on clinical practices.[12] Rather, adult educational experiences that emphasize collaborative learning, direct feedback, and emphasis on clinical applicability appear to yield superior results.[12,13] Similarly, studies of prescribing habits indicate that personalized information "detailing" and feedback can improve substantially a clinician's prescribing

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practices.[14] Davis and colleagues conducted an extensive review of continuing medical education experiences (which included residency training interventions), and categorized these interventions into four types: predisposing, predisposing and enabling, predisposing and reinforcing, and a category combining all three types.[15] "Predisposing" interventions consisted primarily of information-passing: lectures, didactic presentations, and similar experiences. "Predisposing and enabling" programs added information such as practice guidelines, protocols, and algorithms. "Predisposing and reinforcing" curricula included feedback and reminders. Davis's study revealed that programs that used "reinforcing and/or enabling" methods yielded superior results in actually improving significant health outcomes. Green and Mehr's results appear consistent with this latter model: they provided a focused presentation of a validated tool that used a small number of clinically reasonable variables. They followed this presentation with informal reinforcement during periodic service reviews. This was a gentle but apparently powerful intervention that appears to explain the similar CCU admission rates during the control and intervention weeks (we should note that Davis and colleagues also found a "ceiling effect"[15] in several studies, which suggests that physicians had maximized their performance on the basis of previous interventions; this is again consistent with the effects observed in Green and Mehr's study).

Green and Mehr thus provide hopeful information on two fronts: (1) that a quantitatively defined and clinically validated decision tool can gain acceptance when presented in a collaborative, supportive environment that presents subsequent regular feedback, and (2) such decision tools can yield substantial improvement in important clinical outcomes. How can we use these results? First, their findings plus the others mentioned indicate that well-structured and researched clinical protocols, guidelines, and algorithms can serve as the substrate for meaningful educational programs (this should represent good news to the Agency for Health Care Policy and Research and other organizations that have invested significant resources in creating these products). More important, when combined with performance feedback and reinforcement, these tools can lead to substantive improvements in significant clinical outcomes. They also demonstrate that such interventions can proceed fairly informally, incorporating the feedback/reinforcement into regularly occurring educational and clinical activities.

Green and Mehr have demonstrated that the AIHDPI works in a clinical setting distinct from that used for developing the original instrument. This finding in itself provides reassurance that more widespread use of this tool can improve our accuracy in defining acute cardiac ischemia, without endangering our patients. More important, they have provided further insight into how we can structure educational interventions to enhance our decision-making acuity and our patients' outcomes.

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What Alters Physicians' Decisions to Admit to the Coronary Care Unit?

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BACKGROUND. A trial of a decision-support tool to modify utilization of the coronary care unit (CCU) failed because utilization improved after explanation of the tool but before its actual employment in the trial. We investigated this unexpected phenomenon in light of an emerging theory of decision-making under uncertainty.

METHODS. A prospective trial of the decision-support intervention was performed on the Family Practice service at a 100-bed rural hospital. Cards with probability charts from the acute ischemic Heart Disease Predictive Instrument (HDPI) were distributed to residents on the service and withdrawn on alternate weeks.

Residents were encouraged to consult the probability charts when making CCU placement decisions. The study decision was between placement in the CCU and in a monitored nursing bed. Analyses included all patients admitted during the intervention trial year for suspected acute cardiac ischemia (n=89), plus patients admitted in two pretrial periods (n=108 and 50) and one posttrial period (n=45).

RESULTS. In the intervention trial, HDPI use did not affect CCU utilization (odds ratio 1.046, $P>.5$). However, following the description of the instrument at a departmental clinical conference, CCU use markedly declined at least 6 months before the intervention trial (odds ratio 0.165, $P<.001$). Simply in learning about the instrument, residents achieved sensitivity and specificity equal to the instrument's optimum, whether or not they actually used it.

CONCLUSIONS. Physicians introduced to a decision-support tool achieved optimal CCU utilization without actually performing probability estimations. This may have resulted from improved focus on relevant clinical factors identified by the tool. Teaching simple decision-making strategies might effectively reduce unnecessary CCU utilization.

KEY WORDS. Medical decision making; chest pain; physicians' practice patterns; coronary care units. *(J Fam Pract 1997; 45:219-226)*

Decision-support tools to improve the appropriateness of the emergency department disposition of cases of suspected acute cardiac ischemia (myocardial infarction or unstable angina) have been heavily researched over the last two decades.[1-10] One of the motivations for the research on decision support is that educational interventions have generally not yielded significant lasting changes in physician behavior.[11-13]

Unfortunately, while there is extensive literature documenting the validity of decision-support tools for heart disease, they have fared little better than education in effectively changing clinical practice.[14] In two trials that provided decision-support tools for physicians to use or not as they chose, the tools were found to be ineffective; physicians tended not to use them.[15,16] One recent trial providing probability information without human interaction also failed to change behavior.[17] Two trials have demonstrated physician behavior change[2,18]; these trials failed, however, to adequately exclude bias due to nonspecific Hawthorne[19] and sentinel[20,21] effects inherent in how the interventions were applied.

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We report a dramatic change in CCU utilization by a family practice teaching service at a small community hospital. We discovered this change while considering the failure of a trial that aimed to influence physician use of coronary care unit (CCU) services by applying the acute ischemic Heart Disease Predictive Instrument (HDPI).[2] Our findings suggest a potential educational strategy for changing physician decision behavior and emphasize the importance of considering nonspecific effects in interpreting decision-support trials.

FIGURE 1

HDPI Probabilities Chart for Acute Ischemic Heart Disease

Chest Pain = Chief Complaint
EKG (ST, T wave △'s)

History	ST&T Ø	ST ↔	T↑↓	ST↔	ST↔&T↑↓	ST↑↓&T↑↓
No MI& No NTG	19%	35%	42%	54%	62%	78%
MI or NTG	27%	46%	53%	64%	73%	85%
MI and NTG	37%	58%	65%	75%	80%	90%

Chest Pain, NOT Chief Complaint
EKG (ST, T wave △'s)

History	ST&T Ø	ST ↔	T↑↓	ST↔	ST↔&T↑↓	ST↔&T↑↓
No MI& No NTG	10%	21%	26%	36%	45%	64%
MI or NTG	16%	29%	36%	48%	56%	74%
MI and NTG	22%	40%	47%	59%	67%	82%

No Chest Pain
EKG (ST, T wave △'s)

History	ST&T Ø	ST ↔	T↑↓	ST↔	ST↔&T↑↓	ST↔&T↑↓
No MI& No NTG	4%	9%	12%	17%	23%	39%
MI or NTG	6%	14%	17%	25%	32%	51%
MI and NTG	10%	20%	25%	35%	43%	62%

See reverse for definitions and instructions

METHODS

SETTING AND PATIENTS

We studied patients with suspected acute ischemic heart disease (AIHD) admitted to the inpatient Family Practice (FP) service at a 100-bed community hospital. Located in a town of 4000 population, the hospital serves a surrounding community of about 20,000. The population is 98% white, and 68% of local residents are blue-collar workers. For patients with suspected AIHD, an emergency physician (or occasionally an FP outpatient-clinic physician) initially decides on hospitalization; the senior resident on service, with the approval of the attending physician, then decides whether the patient should be placed in the CCU or in a regular nursing bed with ECG telemetry. No administrative incentives, sanctions, or other activities aimed at reducing CCU utilization were initiated at this hospital during any of the study periods.

A retrospective review of all AIHD admissions to the FP service between January 1984 and September 1985 demonstrated very high CCU utilization.[9] In November of 1987, the lead author presented his findings along with a description of the HDPI at a departmental conference. The HDPI is a logistic formula for calculating the probability that a patient has acute ischemic heart disease.[2] It generates a probability score from seven historical and ECG findings, scored dichotomously as present or absent. Subsequently, the appropriateness of CCU utilization was often questioned at department morbidity and mortality conferences.

FIGURE 2

Definitions for Use With HDPI Probabilities Chart

Chest Pain: Patient reports chest or left arm pressure or pain.

Chief Complaint: Patient reports chest/left arm discomfort is most important symptom.

NTG: Patient reports a history of PRN use of nitroglycerin for relief of chest pain. Not necessary to have used NTG for this episode.

MI: Patient reports a history of definite myocardial infarction.

ST ↔: Initial EKG shows ST segment "barring," "straightening," or "flattening" in at least two leads excluding aVR.

ST↑↓: Initial EKG shows ST segment elevation or depression of at least 1 mm in at least two leads excluding aVR.

T↑↓: Initial EKG shows T waves that are "hyperacute" (at least 50% of R-wave amplitude) or inverted at least 1 mm in at least two leads excluding aVR.

Ø: None of the above ST segment or T wave △'s are present.

The HDPI is a decision-support tool. It is not intended as a decision-making device. It supplements, not replaces, clinical judgment.
Certain patients, most notably diabetics, may suffer ischemia and show none or few of the symptoms/signs captured on the HDPI. Other patients, especially those with a history of negative ischemia workups, may have lower probabilities of ischemia than the instrument estimates.

Intervention Procedure

The week before July 1, 1988, the lead author sent to all FP residents a memorandum explaining the study, presenting the literature in support of the HDPI, and outlining the dimensions of the problem of inappropriate CCU utilization. Beginning July 1 and continuing for 1 year, we used an ABAB reversal design: pocket-sized plastic-laminated cards bearing tables of the HDPI's probabilities[22] (Figures 1 and 2) were alternately distributed and withdrawn weekly. As residents rotated through the service and the call schedule, all were exposed to the cards for 2 of their 4 weeks on service, and on one half of their call nights.

Data Collection

The intervention was carried out between July 1, 1988, and June 30, 1989. The medical records of all FP patients aged 35 and older admitted to the hospital during this period were examined, and those admitted for suspected AIHD were collected. Subsequently, we also identically abstracted records for the 6 months preceding and the 6 months following the intervention. A graduate research assistant abstracted each record for demographic information, admission and discharge diagnoses, CCU utilization, peak creatine kinase (CK) level and MB fraction, complications (sustained ventricular arrhythmias, high-grade block, congestive failure, and reinfarction), and HDPI score. All residents who admitted patients during the intervention trial also took part in an unstructured interview designed to assess the instrument's adoptability potential.[23]

Analysis

In reporting our results, we refer to four periods in chronological order of admission dates: period 1 comprises the original retrospective data[9]; period 2 encompasses admissions during the 6 months preceding the intervention; period 3 is made up of admissions during the intervention; and period 4 constitutes admissions during the 6 months following the intervention.

Univariate statistical comparisons were performed, using one-way analysis of variance for interval data and chi-square testing for categorical data. Likelihood-ratio chi-square tests were used when 2×2 comparisons were made. The Kolmogorov-Smirnov statistic was used to compare distributions. Logistic regression was used for all multivariable analyses.

Considering only intervention trial (period 3) patients, we tested the intervention study hypothesis by determining whether the reversal phase (the week using the HDPI, as compared with the week not using the HDPI) was a significant predictor of CCU placement in a logistic regression model. Other independent variables in the model were age, patient sex, physician sex, and HDPI score.

The results of the intervention trial suggested that CCU utilization behavior was much different from the behavior previously experienced at this hospital. To elucidate this, we analyzed CCU utilization in a logistic regression model as a function of time, using as independent variables patient age, sex, HDPI score, and dummy variables for periods 1 through 4. We also plotted the sensitivity and specificity of residents' admission decisions against the HDPI's receiver operating characteristic (ROC) curve. The ROC curve graphically displays the tradeoff between sensitivity and specificity when different cutoff points (in this case, HDPI score) are used to denote a positive test. For the resident, placement in the CCU was considered a positive test. We designated the occurrence of myocardial infarction (defined as an elevation of CK above 150 IU/L with MB fraction more than 5% of total CK) as true disease. The HDPI predicts acute ischemic heart disease, not just myocardial infarction (MI); however, for consideration of the need for CCU admission, MI serves as a reasonable proxy.

RESULTS

PATIENTS

The numbers and characteristics of patients admitted during each of the four periods are displayed in Table 1. Patients did not differ significantly over the periods by HDPI score ($F_{(3)}$ = 1.90, P>.2; Kolmogorov-Smirnov D for period 1 compared with periods 2 through 4 = 0.125, P>.2), sex ($\chi^2_{(3)}$ = 5.92, P>.1), or occurrence of MI ($\chi^2_{(3)}$ = 1.50, P>.6). The periods did differ by age ($F_{(3)}$ = 3.61, P=.014). Subsequent analyses used multivariate logistic regression models to control for the age difference between periods.

The 48 patients admitted to the CCU during the intervention trial used a total of 112 days of CCU care. Fifteen (31%) of these patients sustained an MI; 13 of the 15 had been placed in the CCU at admission. Only 4 intervention trial patients suffered complications requiring CCU services; 2 of these patients died. Three of these patients had been placed in the CCU at admission; the fourth (one of the deaths) had requested do-not-resuscitate status.

CCU UTILIZATION

The hypothesis that use of the HDPI would reduce use of the CCU was not supported: 17 of 30 (57%) patients admitted during weeks using the HDPI and 31 of 59 (53%) admitted during weeks not using it were placed in the CCU. Logistic regression on data from the intervention trial admissions (period 3) disclosed no difference in CCU placement during weeks when resi-

TABLE 1

Characteristics of Patients Admitted with Suspected Acute Ischemic Heart Disease

	Period				
Variable	**1 (1/84-9/85)**	**2 (1/88-6/88)**	**3 (7/88-6/89)**	**4 (7/89-12/89)**	**Total**
No. of patients	108	50	89	45	292
Men/women, no.	65/43	22/28	40/49	23/22	150/142
CCU placement, no.(%)	97 (90)	28 (56)	48 (54)	29 (64)	202 (69)
MI, no.(%)	24 (22)	12 (24)	15 (17)	8 (18)	59 (20)
Mean HDPI	0.411	0.342	0.366	0.416	0.387
Mean age, y	67.2	64.7	68.0	59.9	65.9

CCU denotes coronary care unit; MI, myocardial infarction; HDPI, Heart Disease Predictive Instrument.

dents were using the HDPI compared with those when they were not (odds ratio 1.046, 95% CI 0.36 to 3.0, P>.5). A 1000-trial bootstrap[24] procedure was used to estimate that the probability of the observed no-difference result is only 24% if the HDPI produced a 10% reduction in admission rate from a base rate of 60%.

The finding that only 54% of all patients were placed in the CCU during the intervention period, in contrast to the historical pattern of 90% (compare periods 1 and 3 in Table 1), led us to examine data from the other periods. CCU utilization did differ according to period ($\chi^2_{(3)}$ = 35.8, P<.001). A second logistic regression using three dummy variables to represent the periods confirmed this impression (Table 2). Controlling for age, sex, and HDPI score, period 2 through 4 patients were substantially less likely to be admitted to the CCU than period 1 patients. The adjusted odds ratios for the three variables representing periods 2 through 4, compared with baseline period 1 patients, ranged from 0.145 to 0.175 (Table 2).

The sharp change in admitting practices between period 1 and the subsequent periods is illustrated graphically in Figure 3. Figure 3 is a receiver operating characteristic (ROC) curve for the HDPI that is also marked with point estimates of the performance of the resident physicians. For both the HDPI and the residents, the diagnosis of MI is used as the outcome measure. For the HDPI, various cutoff levels determine a positive test; for the residents, the decision to admit to the CCU is considered a positive test. Between period 1 and the remainder of the study, the residents increased the specificity of their placement decisions without losing sensitivity.

TABLE 2

Logistic Regression Results in Analysis of CCU Utilization

Variable	Weight	Odds Ratio (95% CI)
Age	0.012	1.128* (0.923-1.38)
Male sex	0.81	2.25 (1.26-4.02)
HDPI score	2.66	1.95† (1.39-2.73)
Period 2‡	-1.80	0.165 (0.069-0.398)
Period 3‡	-1.93	0.145 (0.066-0.316)
Period 4‡	-1.74	0.175 (0.069-0.443)

*Odds ratio for one 10-year increment in age.
†Odds ratio for change in HDPI score of 0.25 (eg, 0.50 vs 0.25).
‡Dummy variables representing the four periods, with period 1 as the reference group.

DISCUSSION

Using the HDPI as a decision-support tool, we attempted to improve CCU utilization from historically high levels, only to find that utilization had already changed. The change occurred after the resident physicians learned about the HDPI but before they began using it to actually calculate probabilities. The change persisted for months after the intervention was withdrawn.

Trials of decision-support tools typically document a high percentage of incorrect decisions made by physicians, and either (1) improve those decisions, or (2) fail to do so as a result of physician nonuse of the tool. Our failure and the recently reported unsuccessful trial conducted by Lee and associates[17] are intriguingly different from prior results. In these two studies, the intervention failed to improve decision-making at least in part because the historically high percentage of incorrect decisions had disappeared. In our trial, for the 6 months before, the year during, and the 6 months after our intervention trial, residents made decisions at or near the HDPI's optimum (Figure 3).

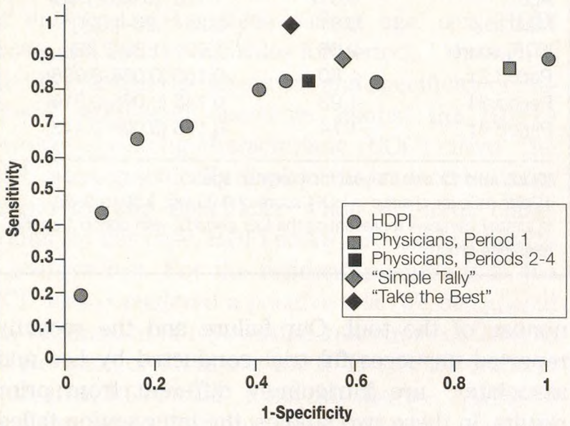
HOW DID THEY DO THAT?

The most interesting findings in research are the unexpected ones, and this outcome was most unexpected. The central surprise is that the residents demonstrated that they could achieve sensitivity and specificity equal to that of a sophisticated regression-based decision-support tool, without actually calculating probabilities. How did they do it?

Let us first dispose of one potential explanation, that the failure of the HDPI to improve decision-making during our trial was an experimental design problem. One might object that the weekly changeover between intervention and control phases allowed "contamination" of the control phase by the intervention phase. This objection fails for two reasons. First, the marked change in CCU admission practices predated the reversal-design intervention (period 3) and persisted after it. Second, the persistence of an effect on weeks when probability calculation was unavailable would demonstrate not "contamination" but that actual calculation of probabilities was unnecessary: that some effect of the HDPI other than its purported decision-support mechanism affected decision-making.

FIGURE 3

Receiver Operating Characteristic Curve for the Heart Disease Predictive Instrument, with Physician Performance



NOTE: Sensitivity and specificity for the HDPI are calcullated for prediction of infarction. For physicians, placement in the coronary care unit is regarded as a physician prediction of infarction. "Simple Tally" and "Take the Best" are simple cognitive decision-making strategies, and are described more fully in the Discussion.

Possible causes for the change include Hawthorne and sentinel effects, a secular trend, and the introduction of the HDPI serving as an unintended and unusual educational intervention. A Hawthorne effect (improvement in performance as a result of increased attention) is unlikely, as the change appeared before period 2 and persisted through period 4, whereas only period 3 contained the direct attention necessary to produce the Hawthorne effect. A sentinel effect (improved performance due to awareness that performance will be reviewed) seems similarly unlikely. After the presentation of the findings of the retrospective review (period 1 data) prior to period 2, low-probability "rule-outs" were often commented on at departmental morbidity and mortality conferences; however, there was no real review of CCU admissions at these conferences or elsewhere, and no consequences attendant upon CCU placements of doubtful necessity. A sentinel effect cannot be completely excluded, however, without a sham-intervention group, which studies of decision support generally lack.

Next let us consider a secular trend. In favor of this explanation are the time between periods 1 and 2 and the turnover of the residents during the interval. Against the secular trend hypothesis are three observations. First, the distribution of HDPI scores did not change across the periods, so the screening of patients in the emergency department was constant. Second, there were no policy changes related to CCU utilization on the part of the department, the residency program, or the hospital during this time. The hospital continued to encourage CCU placement of any patient with chest pain, no matter how low the probability of MI, throughout. Finally, private physicians in this hospital had CCU placement rates similar to those of period 1 through the entire time covered in our data, although the behavior of the other hospital physicians may not be completely comparable to that of our residents.

AN UNINTENTIONAL EDUCATIONAL INTERVENTION?

The possibility that our introduction of the HDPI acted as an educational intervention is suggested by recent work in the psychology of judgment and decision-making. Models of "bounded rationality" recognize that human decision-makers have limited ability to attend to multiple cues and that they process information sequentially rather than integratively. Individuals use simple cognitive strategies collectively referred to as "probabilistic mental models," or PMMs.[25] These strategies employ sequential evaluation of small numbers of cues, usually fewer than 10, and such remarkably simple cognitive strategies as tallying, counting only the positive cues, with no attention to negatives.

A surprising recent finding is that under conditions of uncertainty or limited information, such simple heuristics can lead to decisions equal or superior in accuracy to those achieved by calculation of regression-based models or other sophisticated integrative strategies.[26] The performance of PMMs depends little on the actual strategy but strongly on correct choice of cues. In evaluating suspected AIHD patients, we have found that often physicians pay much attention to "pseudodiagnostic" cues,[27] which impairs their diagnostic accuracy. The seven factors that comprise the HDPI are those that were most strongly predictive of ischemia among 57 variables considered during its development. We believe that exposure to the HDPI changed our residents' admission patterns by teaching them to attend to cues of genuine predictive utility rather than to pseudodiagnostic information.

Could our introduction of the HDPI have been sufficient to bring about this major behavioral change? Although much of the literature on changing physician behaviors has been disappointing, individual or small group sessions to influence drug-prescribing behavior have had significant impact in some settings.[28] Soumerai and Avorn[29] identified 11 important components of successful drug detailing and academic counter-detailing: (1) defining specific problems and objectives; (2) identifying physician motivations for use of a product; (3) establishing credibility; (4) targeting high-potential physicians; (5) involving opinion leaders; (6) two-sided communication; (7) promoting active learner involvement; (8) repetition and reinforcement; (9) use of brief graphic print materials; (10) offering practical alternatives; and (11) selection and training. Introducing the HDPI at a departmental conference and mentioning the appropriateness of CCU admissions in subsequent conferences arguably met many of these criteria (specifically 1, 3 through 8, and 10). Residents had been very high utilizers of CCU services, and a workable alternative (telemetry monitoring outside the CCU) was available. Department conferences were small and relatively interactive in the late 1980s, and the small number of faculty had high credibility with residents. The HDPI's introduction and the conferences appear to have "detailed" the cues of genuine predictive utility.

The unstructured interviews with the FP residents after completion of their time on service lend support to this belief. While the residents could not recall actual probability scores from the chart of predictive instrument probabilities (Figures 1 and 2) they could accurately recall the factors on which the probabilities were based, even several months following completion of the project.

Could a simple cognitive strategy such as a PMM, used by a resident with the correct cues, provide such impressive results? In addition to the residents' performance, Figure 3 is marked with points for the performance of two examples of PMMs: simple tallying, and "take the best." The simple tally is positive if more than two of the HDPI factors are present, negative if not. "Take the best" is positive if the patient has: (1) ST segment changes, or (2) a chief complaint of chest pain plus any one other factor. From the ROC curve, it is apparent that both these simple PMMs performed as well as the HDPI and as well as the residents. More important, both simple PMMs provide examples of how a physician could make decisions equal in accuracy to the HDPI after simply seeing it, ie, without actually calculating probabilities.

These findings are potentially very useful to the primary care physician and to the primary care teacher. The medical decision-making literature contains the unspoken presumption that the human decision process is flawed,[30] and hence must be supplemented by or replaced with decision-analytic or regression-derived decision-support models. Our unexpected findings suggest, on the contrary, that the physician's decision process may perform as well as the best available logistic regression model in at least some situations. The key to such performance is selection of the correct cues. A validated decision-support tool can identify those cues, and a simple intervention can communicate them effectively.

Unexpected findings are seldom unequivocally interpretable, as the experiments in which they were discovered were not designed with them in mind. Our results are no exception. Although we can show the educational hypothesis to be plausible, we cannot exclude all other possible explanations. Our data make it more likely than other possibilities. This study was performed in a small community hospital, the study problem is well defined and circumscribed, and there is a good decision-support tool correctly identifying the important clinical data. To what extent our findings would hold in other settings remains unclear.

CONCLUSIONS

In a setting where a pattern of excessive use existed previously, we found that optimal use of the CCU was achieved following education about, but without the actual use of, a decision-support tool. Explicit probability calculation was not necessary in order to change decision-making.

Existing decision-making research tends to consider typical clinical decision-making inherently defective, and seeks to replace or reform it. These results suggest the possibility of developing strategies, based on the latest judgment and decision-making theory, that could build on the strengths of, rather than seek to replace, clinicians' reasoning. Such strategies could be taught quickly and at low cost. How broadly this technique might be applied remains to be determined.

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