System for Health Area Resource Planning (SHARP): an application to Ontario medical school enrolment

Frank T. Denton, MA, FRSC; Amiram Gafni, DSc; Byron G. Spencer, BA, PhD

Résumé : Le système pour la planification régionale des ressources de la santé (System for Health Area Resource Planning — SHARP) est un système d'ordinateur personnel qui a été conçu pour faciliter la planification des services de santé à long et à court terme en Ontario; des systèmes semblables pourraient être mis au point dans les autres provinces. Grâce au SHARP, les chercheurs peuvent prévoir les demandes futures de services de santé et la disponibilité des ressources nécessaires pour les fournir. Le système comprend sept modèles qui tiennent compte de la population de l'Ontario (SHARP1), de la demande de ressources dans le domaine de la santé (des médecins de 30 spécialités, des infirmières et des auxiliaires dans trois domaines de pratique, d'autres travailleurs de la santé dans 26 catégories et des lits dans 11 services et 14 catégories d'institutions [SHARP2]), la disponibilité du personnel de santé (SHARP3,4,5), le nombre de lits dans les établissements (SHARP6) et le déséquilibre entre la demande et la disponibilité (SHARP7). Les auteurs décrivent le SHARP et font la démonstration de son utilisation pour évaluer l'effet de la réduction du nombre d'inscriptions en première année de médecine que l'on a récemment annoncée en Ontario. Ils montrent que cette baisse réduira le surplus prévu de médecins et entraînera une hausse de la pénurie de services d'internes et de résidents prévue dans les hôpitaux d'enseignement (si on devait limiter le nombre des admissions de stagiaires diplômés venant de l'extérieur de l'Ontario). Cette mesure aura toutefois un effet limité.

Modern health care is expensive, accounting for 7% to 9% of the gross domestic product (GDP) in many developed countries and for a higher percentage in Canada and the United States.[1,2] The cost of health care is a continuing source of concern to federal and provincial governments in Canada. Added to the concern is the fact that the population is both growing and aging rapidly, with important implications for future health care costs.

The complexity of the health care system makes it difficult to control its evolution. A decision to train more or fewer health care workers may not have a significant effect on the stock of care providers for many years. Once trained, such people may remain part of the stock for four decades, or they may relocate to other jurisdictions. This mobility is difficult to predict. Health care technology is advancing rapidly, too, with important but often unforeseeable implications for future practice. As the population ages, the demands on the system change, again in ways that may be difficult to predict. For example, changes in lifestyle may mean that the health care needs of the next generation of elderly Canadians are quite different from those of the present one.

Provincial governments play a leading role in determining the numbers of hospital beds available, applicants accepted into training programs for health care professionals, hospital positions for interns and residents, and so on. Decisions regarding one part of the health care system may not take into account effects on other parts; responses to immediate problems may fail to take into account broader and longer-run consequences. Thus, there is a strong case for a systematic approach to planning.

Professor Denton is in the Department of Economics and the Program for Quantitative Studies in Economics and Population, McMaster University; Dr. Gafni is in the Centre for Health Economics and Policy Analysis, the Department of Clinical Epidemiology and Biostatistics, and the Program for Quantitative Studies in Economics and Population, McMaster University; Dr. Spencer is in the Department of Economics and the Program for Quantitative Studies in Economics and Population, McMaster University, Hamilton, Ont.

The authors are solely responsible for the views expressed herein.

Reprint requests to: Dr. Amiram Gafni, Centre for Health Economics and Policy Analysis, Department of Clinical Epidemiology and Biostatistics, McMaster University, 1200 Main St. W, Hamilton, ON L8N 3Z5; fax (905) 546-5211

← For prescribing information see page 107

In February 1993 the Ontario Ministry of Health announced that first-year medical school enrolment would be reduced by 70, starting in September 1993.[3] This reduction represents a drop of 11% from recent enrolments, and it is in line with a recommendation of the Barer–Stoddart report on medical resource policies in Canada.[4] The report's authors have stated that the purpose of their recommendation was to arrest "the decline in the population–physician ratio" and to encourage "other initiatives that would guard against foreign graduate fill-in."[5] In a statement the Ontario Ministry of Health said it recognized the need for "new guidelines to better control the entry into the health system of graduates of foreign medical schools who come as visa trainees."[3]

In this article we describe a system developed to address the need for integrated long-term planning called the System for Health Area Resource Planning (SHARP). We illustrate its application by exploring future implications of the announced enrolment reduction in Ontario. Since SHARP provides a framework encompassing all major components of the Ontario health care system, it can be used to investigate broad ramifications as well as immediate consequences of policy initiatives. In this regard it is unique.

Overview of SHARP

SHARP is an easy-to-use personal-computer-based system designed to aid in medium- and long-term planning. It consists of seven models (Fig. 1). The first two project the Ontario population and the associated requirements for health care services; the next four project the availability of such services. The results are brought together in a final model that calculates imbalances between the projected requirements and availability. The system makes it easy for users to experiment with alternative ways of reducing imbalances.

SHARP1 projects the Ontario population by age and sex from initial data on age and sex distribution, birth rates by age, death rates by age and sex, immigration and emigration by age and sex, and migration to and from the rest of Canada. In this and other models the outcomes are projected year by year for as many years as the user wishes.

The requirements for health care services are calcu-

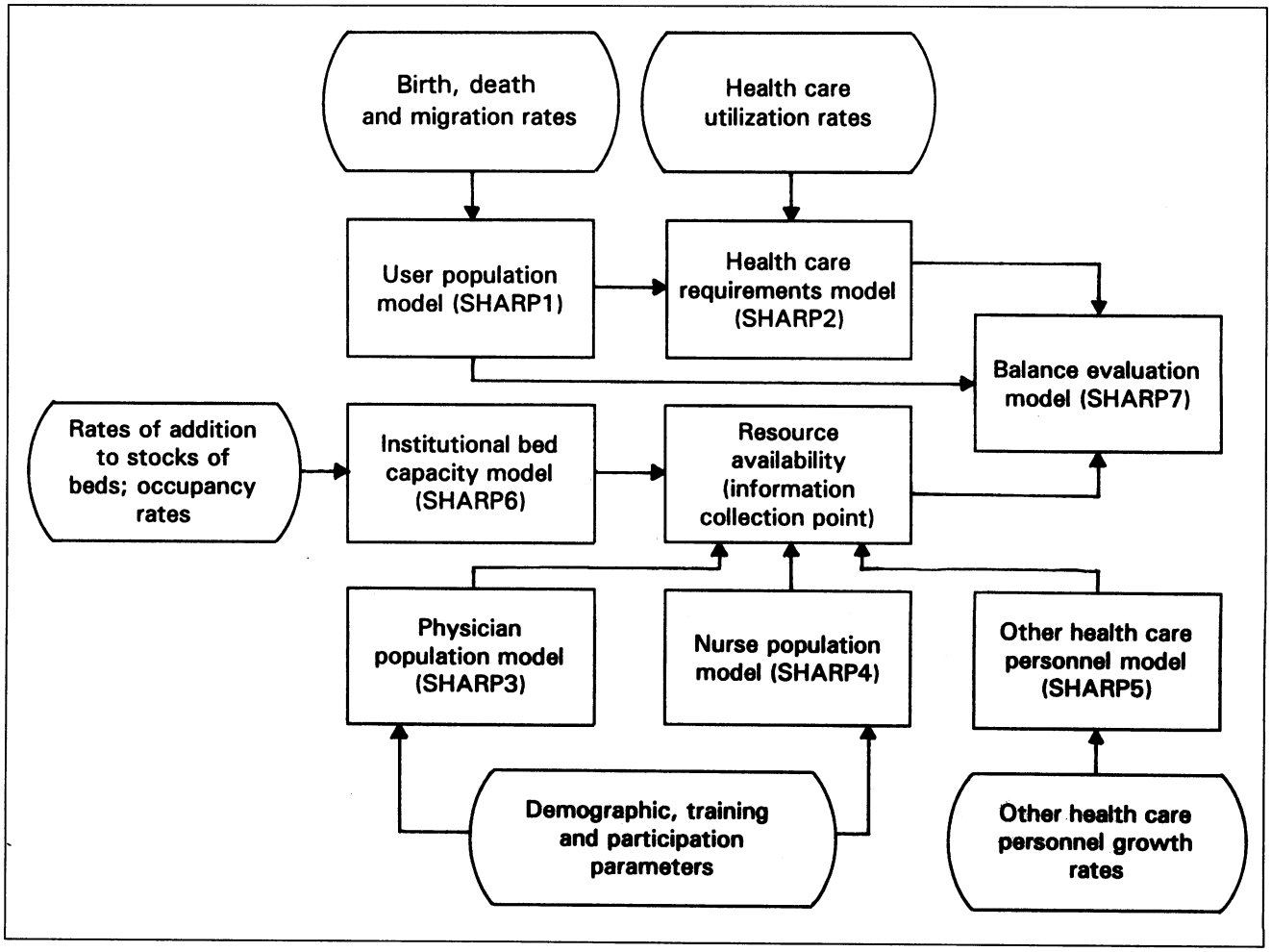

Fig. 1: Configuration of the System for Health Area Resource Planning (SHARP), showing models (rectangles), parameters specified by the user (ovals) and directions of information flow (arrows).

lated in SHARP2. These calculations are based on specifications of average requirements of each age–sex group for each type of health care service. Age-utilization profiles were developed to represent the requirements for the services of physicians in 30 specialties (e.g., general practice, anesthesia and dermatology) and of nonphysician health care personnel (registered nurses and nursing assistants, as well as workers in 26 other categories), for beds in institutions in 11 categories (e.g., medical–surgical and intensive care) and for ambulatory and community care facilities.

Reference levels of service provision are defined from current practice. Although we would have liked to have had needs-based profiles, the data for specifying such profiles do not exist. We therefore based the reference profiles on actual practice. However, a user can alter the profiles to explore the implications of maintaining current delivery practices or of introducing different practices. Future requirements, as defined in SHARP, are independent of the future availability of services; with utilization profiles given, requirements vary only in response to changes in the Ontario population. This distinction between requirements and availability is an essential feature of the system. It must also underlie any rational attempt at planning or policy evaluation.

SHARP3 and SHARP4 are concerned with the numbers of physicians and nurses, respectively, and the availability of their services. These models make separate projections for physicians and nurses by age and sex. In the case of physicians SHARP3 keeps track of 30 specialties based on the Ontario Health Insurance Plan (OHIP) classification system. Standard demographic methods are used to predict the numbers year by year over the projection period and to allow for retirement, death and migration. The model takes into account the path of medical-school graduates from graduation through postgraduate training programs and into the physician population and allows for graduates leaving or entering the province after training. The further training of practising physicians and transfers among specialties are also factored in. The services available are expressed in terms of person-years, to make allowance for the mixture of part-time and full-time practice.

The availability of registered nursing assistants and health care workers in 25 other categories can be projected with the use of SHARP5. Because of limitations in the data the procedures for calculating these services are much simpler. They are based on net growth and participation rates for each category.

The SHARP6 model can project the availability of beds in institutions and ambulatory care. It keeps track of the numbers of beds in 11 categories of care, in each of 14 categories of institution and of 3 types of ambulatory care. Based on initial stocks the future numbers of beds are calculated according to user-supplied assumptions about net rates of addition. Occupancy rates are incorporated, and the numbers of occupied beds are calculated to allow for normal (or assumed) utilization.

The various projections of requirements and availability are brought together in SHARP7, the balance evaluation model. This model takes the health care requirements calculated by SHARP2 and the resource availability calculated by SHARP3, 4, 5 and 6. The population measures from SHARP1 are also used in calculating ratios of resources to population. SHARP7 then generates tables showing the imbalances between requirements and availability and some related calculations. A user can thus determine what changes in personnel, institutional bed capacities or health care delivery practices would be needed to strike a balance between requirements and availability in the various categories. An analysis can be made of the implications for any imbalances of alternative future patterns of health care delivery, medical and nursing school enrolment, and other options. Such analysis provides a basis for informed policy decisions. Detailed descriptions of the models and computer documentation are available.[6]

SHARP database

Values are provided for all parameters, based on the best available data for a recent year. (A full description of how values were assigned is provided in the *SHARP System User Manuals*.[6]) SHARP projections draw on a large volume of data. One benefit of developing the system was the identification of gaps and problems in the information available. To maintain the system's usefulness the database must be updated as new information and improved estimates become available.

The current utilization profiles are derived from unpublished OHIP physician billing data, measures of institutional bed utilization by age and sex from Statistics Canada and the Ontario Ministry of Health and a range of other statistical sources or informed judgements of health care specialists. The initial population of physicians (by age, sex and specialty) is based on records of the Ontario Physician Manpower Data Centre (adjusted to correspond to OHIP totals), of nurses (by age and sex) on data from the College of Nurses of Ontario, of interns and residents (by age, sex and number of years in training) on information from the Canadian Post-MD Registry Census, and of other health care professionals on data from *Health Personnel in Canada*, published by Health Canada; the initial stocks of institutional beds (by category of care and of institution) and ambulatory visits (by type) are based on data from the Ontario Ministry of Health and other sources.

Effects of reducing medical school enrolment

SHARP can be used to explore the implications of the reduction in medical school enrolment and of alternative decisions affecting postgraduate training. (Other applications have been reported elsewhere.[7,8]) As shown

in Table 1, in 1990 there were an estimated 19 259 physicians in active practice in Ontario. (The practical difficulties in obtaining accurate figures in British Columbia are discussed by Barer, Fung and Hsu.[9]) Slightly less than 50% of physicians were classified as being in general practice or family medicine. There were 587 graduates from Ontario medical schools and 3036 interns or residents. (The number of interns and residents is of interest both as an indicator of the training process that renews or augments the stock of physicians and as an indicator of the number of *de facto* providers of services, chiefly in teaching hospitals. Fellows are grouped with interns and residents. Because some fellows are practising physicians undertaking additional training, some double counting may result when they are subsequently added to the physician population; however, our evaluation of the data indicates that this is not a serious problem.) Table 1 shows projections for the years 2000 and 2010 in six alternative cases.

The reference case shows what would happen without any reduction in first-year enrolment. Both the number of students graduating from Ontario medical schools and the population of interns and residents would differ little from their 1990 levels. The number of physicians would grow by 32.9% between 1990 and 2000, and by a further 23.0% between 2000 and 2010. This growth would result from the addition of physicians who completed postgraduate training and remained in Ontario (including many graduates of medical schools outside Ontario) and the migration of qualified physicians to Ontario, after allowance for emigration, retirement and death. The projected growth would be somewhat more rapid for physicians in general practice and family medicine than for those in other specialties.

We assumed that migration to Ontario is balanced by out-migration of both newly qualified and previously qualified physicians. This assumption is conservative and roughly consistent with 1992 estimates showing that

Table 1: Projected effects of alternative policy measures on numbers and growth rates of Ontario medical school graduates, interns and residents, and physicians

Projection assumptions	Year	Population				Growth in no. of physicians over 10 yr, %		
		Medical school graduates	Interns and residents	All physicians	Physicians in GP/FM*	All	In GP/FM	In other specialties
Baseline estimate	1990	587	3 036	19 259	9 580	–	–	–
1. Reference case	2000	595	3 001	25 596	13 178	32.9	37.6	28.3
	2010	595	3 001	31 477	16 551	23.0	25.6	20.2
2. First-year undergraduate enrolment reduced by 70	2000	527	2 828	25 557	13 138	32.7	37.1	28.3
	2010	527	2 751	30 602	16 049	19.7	22.2	17.2
3. As in case 2 with no reduction in postgraduate training	2000	527	3 001	25 596	13 178	32.9	37.6	28.3
	2010	527	3 001	31 477	16 551	23.0	25.6	20.2
4. As in case 2 with half the reduction in postgraduate training envisaged in case 1	2000	527	2 914	25 577	13 158	32.8	37.3	28.3
	2010	527	2 876	31 039	16 300	21.4	23.9	18.7
5. As in case 2 with reduced numbers in specialized postgraduate training	2000	527	2 544	25 690	13 521	33.4	41.1	25.7
	2010	527	2 486	30 422	17 049	18.4	26.1	9.9
6. As in case 2 with greatly reduced numbers in specialized postgraduate training	2000	527	2 298	25 792	13 864	33.9	44.7	23.2
	2010	527	2 254	30 235	17 923	17.2	29.3	3.2

*GP/FM = general practice and family medicine.

364 physicians — including interns and residents — moved out of the province while 346 moved to it; however, accurate estimates of migration are hard to come by, as are accurate estimates of many aspects of the health care system.

The second projection in Table 1 assumes a reduction of 70 in first-year enrolment starting in 1993. By 1997 the size of the graduating class would be smaller, and, hence, there would be fewer entrants from Ontario medical schools to the intern–resident stream. (The number graduating is reduced by somewhat less than 70 because of normal attrition.) Without any further changes, entrants would continue to come from outside Ontario, but it is assumed that their numbers would decline in the same proportion as the numbers of entrants from within Ontario. A decline in the enrolment of out-of-province graduates in training programs could result from curtailment of enrolment in medical schools outside of Ontario or from explicit government ceilings. Our assumption that out-of-province graduates will decline in the same proportion as Ontario ones is arbitrary but is consistent with the recommendation of the Barer–Stoddart report concerning "the need for about a 10% reduction in the overall numbers of post-MD training positions."[10] With the reduction in the number of entrants to the postgraduate programs the projected number of interns and residents would decrease, and the growth of the number of physicians would subsequently be reduced as well. However, the impact would be relatively small and would not appear for several years. Compared with the reference case the number of interns and residents would be reduced by about 6% by the year 2000 and about 8% by 2010. The effect on the number of physicians would be even more gradual: compared with the reference case the physician population would be reduced by only 39 (less than 0.2%) by the year 2000, and by 875 (less than 3%) by 2010.

Fig. 2 shows the numbers of physicians and of interns and residents with and without the enrolment change. The very small impact of the policy is evident.

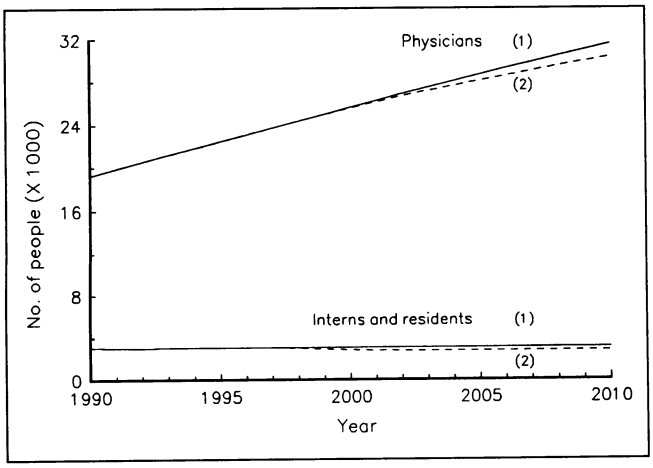

Fig. 2: Projected populations of physicians and of interns and residents (1) without and (2) with a proposed reduction of 70 in first-year undergraduate enrolment.

The Ontario population is projected to grow by 18.9% between 1990 and 2000 and by a further 15.5% between 2000 and 2010; the rate of growth in the number of physicians will be higher than that of the population. In the Ontario population growth projection it is assumed that the number of births per woman will remain at the current level at each age, death rates will continue to decline moderately, migration to and from the rest of Canada will continue at recent rates, and net immigration to Ontario from other countries will be consistent with recent rates and with planned immigration targets.

The third and fourth cases in Table 1 show that reductions in the size of postgraduate programs, as well as in the number of medical school graduates, are needed to produce a significant effect on the size of the physician population. The third case shows the effect of no reduction: postgraduate enrolment from outside Ontario increases enough just to offset the reduction in the number of graduates of Ontario medical schools. The fourth set of projections shows the result of a reduction in enrolment in postgraduate programs of 87 by 2000 and of 125 by 2010 — half-way between the enrolment projected in the reference case and that projected if medical school enrolment were reduced by 70. That is, enrolment from outside Ontario only offsets half the reduction in the number of Ontario graduates. As in the other cases, the result would be continued rapid growth of the physician population.

In the fifth and sixth cases in Table 1 it is assumed that the specialty composition of postgraduate training shifts and the numbers of entrants in the first year of training are the same as in the case of reduced undergraduate enrolment. The fifth case is based on a larger proportion of physicians terminating training after they qualify for general practice or family medicine than in the case of reduced undergraduate enrolment (only 90% as many physicians continue training beyond the second postgraduate year). In the sixth case that proportion is lowered to 80%. One result of these changes is, of course, a reduction in the overall numbers of interns and residents. As well, the number of physicians is somewhat higher by the year 2000 than it would otherwise be, because trainees enter practice sooner. However, the number of physicians is lower than in other cases by the year 2010, as the effect of the policy change on the flow of trainees becomes evident. Even so, there is continued rapid growth in the number of physicians, especially those in family medicine and general practice.

Table 2 shows calculations from SHARP7, the balance evaluation model. Imbalances between service requirements and availability are calculated using actual 1990 utilization patterns as the standard, leaving an imbalance of 0. The ratio of population to physicians (whether practising part time or full time) was 506 in Ontario in 1990. With the effect of part-time practice taken into account, there were 179.6 full-time equivalent (FTE) physicians per 100 000 people.

With no change in policy the population–physician ratio would fall to 425 by 2010, a drop of about 16%, and the FTE physician–population ratio would rise by about 16%. This indicates a projected surplus of physician services compared with 1990 of more than 10% by 2010. The surplus would be much greater among physicians in general practice and family medicine than among those in the other specialties taken together. At the same time, there would be a substantial deficit in intern and resident services of about 27% by 2000 and about 57% by 2010.

These calculations allow for the aging of and increase in the future population. The projected surpluses or deficits are based on the reference year of 1990. Had an earlier year been chosen, the projected surplus of physician services would have been even greater.

The several policy variants show broadly similar results when first-year enrolment is reduced (Table 2): a substantial reduction in the physician–population ratio, a substantial increase in the surplus of physicians and a large shortfall of interns and residents (as service providers). If the proportion of physicians qualifying for general practice and family medicine were increased, there would be a shortfall of physicians in other specialties and a larger surplus of physicians in general practice and family medicine than in the reference case. In all cases, there is a very large projected deficit in the services of interns and residents. Even without the reduction in first-year enrolment it appears that alternative means of providing services in teaching hospitals must be found in future. Recognizing this shortfall, Barer and Stoddart[10] recommended that "necessary clinical services currently provided by residents, but which are not essential for their specialty training, should be provided by other configurations of health care personnel (including possibly nonphysician personnel)."

Table 2: Projected effects of alternative policy measures on population–physician ratios and service imbalances in Ontario

Projection assumptions	Year	Population per physician	No. of FTE* physicians per 100 000 population	Service imbalance,†%			
				Interns and residents	All physicians	In GP/FM	In other specialties
Baseline estimate	1990	506	179.6	0.0	0.0	0.0	0.0
1. Reference case	2000	453	197.7	–27.2	7.6	11.0	4.0
	2010	425	208.0	–57.3	10.5	15.4	5.1
2. First year undergraduate enrolment reduced by 70	2000	454	197.4	–35.0	7.5	10.7	4.0
	2010	438	202.1	–71.6	7.8	12.7	2.6
3. As in case 2 with no reduction in post-graduate training	2000	453	197.7	–27.2	7.6	11.0	4.0
	2010	425	208.0	–57.3	10.5	15.4	5.1
4. As in case 2 with half the reduction in postgraduate training envisaged in case 1	2000	453	197.6	–31.0	7.5	10.9	4.0
	2010	431	205.0	–64.1	9.2	14.1	3.8
5. As in case 2 with reduced numbers in specialized postgraduate training	2000	451	198.5	–50.0	8.0	13.4	2.0
	2010	440	200.9	–89.9	7.3	18.2	–6.3
6. As in case 2 with greatly reduced numbers in specialized postgraduate training	2000	449	199.4	–66.1	8.4	15.6	0.0
	2010	443	199.6	–109.4	6.7	22.4	–15.8

*FTE = full-time equivalent.
†Based on differences between required number of person-years of service and total person-years available as a percentage of availability. Part-time practice has been converted to FTEs.

Discussion

SHARP provides a comprehensive framework for assessing the consequences of changes in population, service delivery patterns and health care policy in the medium and long term. It also facilitates and encourages analysis of the effects on the health care system as a whole of changes in particular components. It could assist, for example, in the analysis of many recommendations contained in the Barer–Stoddart report.[4]

With SHARP we have shown that, with no reduction in Ontario medical school enrolment, the population–physician ratio would continue to fall and would be about 16% lower in 2010 than in 1990. There would be a substantial surplus of physician services and a very large shortfall in the services now provided by interns and residents. The 1993 reduction in medical school enrolment will reduce this surplus as long as the numbers of postgraduate trainees from outside Ontario are also restricted; however, the effects of the reduction will be small. It will also result in substantial increases in the shortfall of services of interns and residents. Thus, the SHARP projection shows that it will be impossible to maintain current delivery practices and that adjustments will be needed.

The accuracy of any projection depends on realistic assumptions about the responses to policy initiatives and on the quality of the data. One benefit of our work has been the identification of gaps and inconsistencies in the information available. SHARP must be maintained and updated in order to remain useful. New information must be incorporated, patterns of utilization must be adjusted to reflect changes in practice that are consistent with health care requirements, and the model design and software must be modified to meet the changing demands of SHARP users.

How can SHARP be evaluated? SHARP does two things: it provides a way of conceptualizing the operation of the health care system, and it quantifies the relations in that system. The conceptual framework must be judged through informed responses and comments from experts. The central issue is whether it is useful to distinguish between the requirements for health care and the availability of resources to meet them, and then to consider ways to balance needs and resources. The main advantage of the view of health care as an integrated system is that it encourages policymakers to consider alternative ways in which services might be provided. For example, if inpatient services are reduced, what are the implications for outpatient services and community care in general? On the matter of quantifying the relations, the projections based on other available models can be compared directly with those from SHARP. As an example, we have compared our projections with ones provided in a report to the deputy ministers of health.[11] The two sets of projections are similar.

SHARP involves considerable abstraction from the complexity of the health care system; it is, therefore, not suitable for all projection purposes. We have considered several possible extensions of the system, including the introduction of cost functions (to permit the calculation of health care costs in dollar terms; current calculations are only in terms of human and physical resource usage) and the creation of a version suitable for application to regions within Ontario. We have also considered the development of a national version of SHARP, since, with free movement of both health care consumers and providers, human resource planning issues are best addressed at the national level.

We thank Drs. Morris Barer and Greg Stoddart for their comments on an earlier draft and Christine Feaver, Mark Brockington, Neno Li-Ritchie and Barbara Markham for research assistance. We have benefitted, too, from remarks by participants at conferences, seminars and meetings at which we presented SHARP.

The development of SHARP was supported by the Ontario Premier's Council on Health, Well-Being and Social Justice Health Innovation Fund, and additional support was provided by the Institute for Clinical Evaluative Sciences.

References

1. Health care survey. *The Economist* 1991; 320 (7714): 4
2. Schieber GJ, Poullier JP, Greenwald LM: Health care systems in 24 countries. *Health Aff* 1991; 10 (3): 22–38
3. *Ontario Medical School to Take Fewer Students* [news release], Ontario Ministry of Health, Feb 18, 1993
4. Barer ML, Stoddart GL: *Toward Integrated Medical Resource Policies for Canada.* Prepared for the Federal/Provincial/Territorial Conference of Deputy Ministers of Health, 1991: 20
5. Barer ML, Stoddart GL: Toward integrated medical resource policies for Canada: 7. Undergraduate medical training. *Can Med Assoc J* 1992; 147: 305–312
6. Denton FT, Feaver CH, Gafni A et al: *SHARP System User Manuals*, Program for Quantitative Studies in Economics and Population, McMaster University, Hamilton, Ont, 1993
7. Denton FT, Gafni A, Spencer BG: Resource requirements and availability: an integrated system of models for health care planning. In Chytil MK, Duru G, van Eimeren W et al (eds): *Health Systems — the Challenge of Change: Proceedings of the 5th International Conference on System Science in Health Care*, Omnipress Publishing, Prague, Czech Republic, 1992: 635–638
8. Denton FT, Gafni A, Spencer BG: The SHARP computer system: a tool for resource planning in the health care sector. In Malek M, Rasquinha J, Vacani P (eds): *Strategic Issues in Health Care Management*, John Wiley & Sons, New York, 1993: 45–56
9. Barer ML, Fung PW, Hsu D: Referral patterns, full-time equivalents and the "effective" supply of physician services in British Columbia. In Boan JA (ed): *Proceedings of the 2nd Canadian Conference on Health Economics*, University of Regina, Regina, 1984: 285–335
10. Barer ML, Stoddart GL: *Toward Integrated Medical Resource Policies for Canada.* Prepared for the Federal/Provincial/Territorial Conference of Deputy Ministers of Health, 1991: 22
11. *Report of the National Coordinating Committee on Postgraduate Medical Training.* Prepared for the Federal/Provincial/Territorial Conference of Deputy Ministers of Health, 1992: Appendix I