Return to August 2000 Table of Contents

ORIGINAL ARTICLE

Variation in time spent on the waiting list for elective vascular surgery: a case study

Boris Sobolev, PhD
Peter Brown, MD
David Zelt, MD, MSc

Dr. Sobolev is with the Queen's Health Policy Research Unit, the Department of Surgery and the Department of Community Health and Epidemiology, Queen's University. Drs. Brown and Zelt are with the Department of Surgery, Queen's University, Kingston, Ont.

Medical subject headings: health services accessibility; health services administration; health services research; hospital surgery department; surgical procedures, elective; vascular surgical procedures; waiting lists

(Original manuscript submitted Feb. 17, 2000; received in revised form June 5, 2000; accepted June 19, 2000)

Clin Invest Med 2000;23(4):227-38.

Abstract

Objective: To review the variation in time spent on the waiting list for elective vascular surgery provided by a single team of specialists.
Design: A prospective cohort study.
Setting: An acute care hospital in Ontario.
Population: One thousand and eighty-four consecutive patients with vascular problems accepted for elective surgery between 1994 and 1998.
Interventions: Abdominal aortic aneurysm (AAA) repair; carotid endarterectomy (CAD); surgery for peripheral vascular disease (PVD); and arteriovenous fistula (AVF) for long-term access in patients with renal failure.
Outcome measures: Time-to-treatment curves, admission rates.
Results: The weekly admission rate was 9.8% on average. The proportion of patients who underwent operation was 50% at 7 weeks, 75% at 14 weeks and 90% at 26 weeks. The weekly admission rate varied according to clinical priority, from 42% in priority class 1 to 6% in class 5. In any priority class, the admission rate was not constant over time. Although the proportion of patients operated on within the maximum recommended time in classes 1, 2, 3 and 4 was 52%, 50%, 35% and 20% respectively, the last 10% of patients waited 5 to 16 weeks, 10 to 16 weeks, 16 to 37 weeks, and 25 to 39 weeks respectively. There were statistically significant differences in waiting time by surgical procedure among the least urgent cases, with median times of 7, 10 and 19 weeks for AVF, PVD and CAD procedures, respectively.
Conclusions: When queuing procedures are uniform, the waiting times for access to elective vascular surgery provided by the same team of specialists differ considerably for patients with equal surgical needs and urgency. It remains to be examined whether delays in scheduling operations and cancellations affect the waiting time after adjustment for urgency and comorbidity.

Résumé

Objectif : Examiner la variation du temps passé sur les listes d'attente avant de subir une intervention de chirurgie vasculaire élective pratiquée par une seule équipe de spécialistes.
Conception : Étude prospective de cohorte.
Contexte : Hôpital de soins actifs de l'Ontario.
Population : Mille quatre-vingt-quatre patients consécutifs qui avaient des problèmes vasculaires et qui ont été acceptés pour une chirurgie élective entre 1994 et 1998.
Interventions : Intervention de correction d'un anévrisme de l'aorte abdominale (AAA); endartérectomie carotidienne (CAD); intervention chirurgicale de correction d'une maladie vasculaire périphérique (MVP); fistule artérioveineuse (FAV) pour accès de longue durée chez des patients atteints d'insuffisance rénale.
Mesures de résultats : Courbes des périodes d'attente jusqu'au traitement, taux d'admission.
Résultats : Le taux d'admission hebdomadaire s'est établi à 9,8 % en moyenne. Le pourcentage des patients qui ont subi une intervention a atteint 50 % à 7 semaines, 75 % à 14 semaines et 90 % à 26 semaines. Le taux d'ad-

mission hebdomadaire a varié, en fonction de la priorité clinique, de 42 % pour la catégorie prioritaire 1 à 6 % pour la catégorie 5. Le taux d'admission n'était constant dans le temps pour aucune catégorie de priorité. Même si le pourcentage des patients qui ont subi une intervention en deçà de la période recommandée maximale des catégories 1, 2, 3 et 4 s'est établi à 52 %, 50 %, 35 % et 20 % respectivement, les patients de la dernière tranche de 10 % ont attendu de 5 à 16 semaines, de 10 à 16 semaines, de 16 à 37 semaines et de 25 à 39 semaines respectivement. On a enregistré des différences significatives sur le plan statistique quant aux périodes d'attente selon l'intervention chirurgicale parmi les cas les moins urgents et les durées médianes ont atteint 7, 10 et 19 semaines dans le cas des interventions FAV, MPV et CAD respectivement.

Conclusions : Lorsque les procédures d'établissement des files d'attente sont uniformes, les périodes d'attente pour avoir accès à une intervention de chirurgie vasculaire élective pratiquée par la même équipe de spécialistes diffèrent considérablement chez les patients dont les besoins chirurgicaux et l'urgence de l'état sont les mêmes. Il reste à déterminer si les interventions tardives et les annulations ont une incidence sur la période d'attente, après rajustement en fonction de l'urgence et de la comorbidité.

Introduction

In Canadian health care, it is common practice to put patients who need elective procedures and cannot be served immediately on a waiting list. Although waiting lists contain patients with differing clinical priorities, there are few areas in which policies on how to share services between competing needs have been developed. Therefore, depending on queuing practices, patients may not receive attention on the basis of need and urgency.[1]

The length of time that patients spend on waiting lists for elective surgery has been examined in a number of studies, both in and outside Canada. These studies reported variations in waiting times across surgical procedures, care providers, funding plans, socioeconomic status and the hospital affiliation of referring physicians.[2–11] However, few empirical studies have been concerned with the variation of waiting times in a queue for service by one provider. It is, therefore, unclear whether these waiting times vary more than would be expected by chance alone or whether other factors are involved. The objective of this study was to review the variation in time spent on the waiting list for elective vascular surgery provided by the same team of specialists, where queuing procedures were uniform. We were primarily concerned with the statistical variation in duration of waiting in a queue of patients with equal surgical needs and urgency.

This study made use of data from the waiting-time registry in the Division of Vascular Surgery of the Queen's University Department of Surgery. This department is centred primarily at the Kingston General Hospital, a 448-bed tertiary referral centre for more than 500 000 residents of southeastern Ontario. We described the variation of times from acceptance to admission for elective vascular surgery and the rates at which patients were selected for treatment from the waiting list.

Methods

Access to elective surgery

Access to surgical procedures provided in hospital operating rooms (ORs) is managed through an OR schedule. To plan the utilization of OR resources, the hospital allocates blocks of OR time and bed availability to each surgical service, which then places their patients on the schedule. Within the services, patients are selected for scheduling based on urgency, best use of allocated OR time and the availability of other hospital resources.

An emergency patient is allowed to enter the OR upon arrival, causing cancellation of scheduled elective operations. On the other hand, the need to avoid idle OR time creates opportunities for the immediate admission for purely elective cases. For example, if OR time is available from the previous planning cycle, the specialist may decide to add an elective patient to the current schedule immediately after the decision to perform surgery is made. Or, if OR time becomes available unexpectedly, already scheduled patients might be asked to go in ahead of their scheduled dates.

Waiting-list management

The Division of Vascular Surgery uses a computerized registry to keep track of all patients referred to the service. It also maintains a waiting list to manage access to care for all patients accepted for elective surgery. Waiting-list management includes adding patients to the list, assigning urgency status, scheduling admission dates and removing patients from the list. Patients are placed on the list after the decision to perform surgery is made, if they cannot be immediately added to the current OR schedule. Patients are ranked by how urgently they need treatment, and a priority class is assigned to each patient to determine their relative position on the list. Patients with a higher priority will be selected for surgery ahead of those with a lower priority, regardless of when they entered the list. Patients in the same priority class are selected in the order of arrival. Before being added to the OR schedule, all patients are assessed by their surgeon as to suitability for surgery. If a patient is deemed unfit, scheduling the operation may be postponed.

Patients admitted for surgery are removed from the waiting list. A patient may be also removed from the list without admission for reasons that preclude scheduling an operation. For example, the patient's condition deteriorated and the surgical risk became too great, the patient died while awaiting operation, the patient decided against surgery, the patient's condition improved and made the operation unnecessary.

Source of data

The waiting-time registry was set up to prospectively collect data on how long it takes to receive treatment in a cohort of patients accepted for elective vascular surgery.[12] The registry records include all patients referred to the division for outpatient clinic assessment and then added to the waiting list. Not included were patients seen on an emergency basis outside the clinic and patients who underwent emergency surgery.

Variables from the registry records

Data on the following variables were taken from the registry records: gender, date of birth, surgical procedure, maximum recommended waiting time, date of acceptance on the waiting list, date of admission to hospital for surgery and the date and reason for removal from the waiting list if the patient did not undergo surgery.

Elective surgical procedures

Three main vascular procedures were examined: abdominal aortic aneurysm (AAA) repair (*Canadian Classification of Procedures* [CCP] codes 50.24, 50.34, 50.36, 51.25, 51.29[13] with *International Classification of Diseases*, 9th revision [ICD] codes 441.3, 441.4, 441.5, or 441.6[14]); carotid endarterectomy (CAD) (CCP code 50.12); and peripheral vascular bypass surgery, other arterial reconstructive and graft procedures involving blood supply to the legs (CCP codes 51.29, 51.25 in the absence of ICD codes 441.3, 441.4, 441.5, or 441.6).[13] A fourth procedure studied was arteriovenous fistula (AVF) (CCP code 51.27) to provide long-term access for patients having renal failure.

Maximum recommended waiting time

Vascular surgery is an area of medical care in which urgency of intervention can be clearly defined.[15,16] AAA repair is undertaken to prevent or treat rupture of the aorta. It is widely accepted that the larger the diameter of the aneurysm, the greater is the risk of rupture and, therefore, the higher the urgency of surgery.[15] CAD is performed to prevent stroke, the dreaded outcome of atherosclerotic blockage in major arteries on either side of the neck. CAD in patients with symptomatic disease is considered more urgent than in patients with asymptomatic disease, even if the carotid stenosis is of equal degree. In the case of peripheral vascular disease (PVD), the surgical procedures to restore blood flow to the legs involve placement of grafts to bypass blockage between the iliac arteries. Early occlusive lesions often present as claudication (pain on walking). When lesions become more widespread and reduce blood flow to critically low levels, there may be pain at rest and gangrene of the tissues. Patients in this group are considered to most urgently require surgical intervention for limb salvage.

Internal guidelines have been set out for the number of days a patient can safely wait for surgery. These guidelines ensure that patients receive treatment according to surgical need and urgency. The guidelines were a consensus within the Division of Vascular Surgery, based on clinical experience and the existing literature. Maximum recommended waiting times are: 7 days for repair of AAA more than 8 cm in size and bypass surgery for PVD with pain at rest; 14 days for repair of AAA 6 to 8 cm in size; 21 days for endarterectomy for symptomatic carotid artery disease; 28 days for repair of AAA less than 6 cm in size; and 90 days for endarterectomy for asymptomatic carotid disease, AVFs for hemodialysis access, peripheral vascular bypass surgery for claudication, and other reconstructive procedures.

Date of acceptance on waiting list

Patients are added to the waiting list after a consultation visit in which surgery is deemed necessary. The date of the surgeon's letter to the patient's referring primary care physician regarding the acceptance for surgery serves as the date of acceptance onto the list.

Date of admission to hospital for surgery

The actual dates when patients were admitted to hospital for surgery came from the hospital information system.

Date and reason for removal from the list

Some patients were removed from the list without undergoing operation for any of the following reasons: a scheduled procedure was cancelled because the patient was considered unfit for the operation; the patient's condition precluded scheduling surgery; the patient died while awaiting surgery; the patient decided against surgery; or, the patient's condition improved and made the surgical procedure unnecessary. The date of removal was recorded by the Division of Vascular Surgery.

Derived variables

Waiting time

Calendar weeks spent on the waiting list served as the natural counting unit of time because a patient could be scheduled and admitted for elective surgery only through the list. For those who underwent surgery, waiting time was calculated as the number of weeks between the date they were added to the waiting list and the date they were admitted to hospital for the procedure. For those removed from the waiting list without surgery, the waiting time was calculated as the number of weeks between the date they were added to the list and the date of removal. For the patients who were still on the list at the end of the study, the waiting time was calculated as the number of weeks between the date they were added to the list and June 30, 1999.

Priority class

On the basis of their recommended waiting time, each patient was assigned a priority class between 1 and 5 (lower number has higher priority) to determine their relative position on the waiting list, regardless of the date they were added to the list.

Indicator of censored observation

Waiting outcomes were divided into 3 general categories: surgery performed, removed from the list without surgery, and still on the list. A censorship indicator was assigned to each observation of waiting time. The indicator had the value of 1, if the outcome was "removed without surgery" or "still on the list."

Study population

All patients accepted for elective vascular surgery were eligible for the study. The registry has records for 1089 consecutive cases added to the waiting list between July 1, 1994, and Dec. 31, 1998. Five patients were excluded from the study because missing clinical records made it impossible to determine whether their unusually long waiting times (more than 2 years) were a result of clerical error or actual waiting, leaving a study population of 1084. The study's follow-up period was 6 months from the date when the last patients were added to the list.

Table 1 describes the distribution of patients by gender, age, priority class and year of acceptance on the waiting list. More than two-thirds of the patients placed on the list were men, and the majority of them (94.8%) were aged 45 years and older. AAA, carotid artery disease, and PVD due to atherosclerotic occlusion made up the majority of the problems encountered. Venous diseases, such as varicose veins and chronic venous insufficiency, made up a small percentage of diseases seen and treated by the Division of Vascular Surgery. The small number of patients added to the waiting list in 1994 (8.0%), compared with over 20% for each subsequent year, reflects the fact that the registry was started in July 1994.

Of 1084 consecutive patients, 985 underwent surgery, 14 were still waiting at the end of the follow-up period and 85 were removed from the list without surgery for a variety of reasons: the patient's condition improved (19 patients), the patient died while awaiting surgery (3), the surgical risk became too great (38) or the patient decided against surgery (25).

Table 1: Demographic features and characteristics of 1084 patients on the waiting list for elective vascular surgery

Characteristic	No. (and %) of patients
Gender	
Females	352 (32.5)
Males	732 (67.5)
Age group	
< 45	56 (5.2)
45–64	287 (26.5)
65–74	448 (41.3)
≥ 75	293 (27.0)
Year of entry on the list	
1994	87 (8.0)
1995	242 (22.3)
1996	223 (20.6)
1997	241 (22.2)
1998	291 (26.8)
Surgical procedure	
AAA repair	311 (28.7)
CAD	264 (24.2)
PVD surgery	360 (33.2)
AVF for hemodialysis	149 (13.7)
Priority class	
1 (most urgent)	205 (18.9)
2	95 (8.8)
3	149 (13.7)
4	203 (18.7)
5 (least urgent)	432 (39.9)

AAA = abdominal aortic aneurysm, CAD = carotid endarterectomy, PVD = peripheral vascular disease, AVF = arteriovenous fistula.

Statistical analysis

The access function estimation

Waiting times were analysed as prospectively collected observations. All patients removed from the waiting list without surgery were treated as censored observations. The cumulative probability of receiving surgery as a function of time spent on the waiting list, the access function, was estimated by the product-limit method.[17] The access function estimate was presented by a time-to-treatment curve that describes the cumulative percentage of patients undergoing surgery at a certain week on the list. With use of the log-rank and Wilcoxon tests, the access to surgery was compared by gender, age, procedure and priority class.[18]

Admission rate

To calculate the average weekly admission rate we divided the number of admissions by total number of patient-weeks on the list. The rate was also calculated for each week spent on the waiting list as the number of admissions during the given week among patients who had waited until that week. Crude rate ratios were estimated using the Poisson log-linear regression model. An assessment was made to determine whether the admission rate was constant over the time patients spent on the waiting list by testing the null hypothesis that the waiting-time distribution is exponential. The rationale is that a constant rate corresponds to exponential waiting-times distribution.[17]

Results

Access to surgery

There was considerable variation in waiting times for elective vascular surgery. Fig. 1 shows the proportion of patients receiving treatment as a function of time since placement on the waiting list. The proportion rose rapidly, reaching 40% after 4 weeks, 50% at 7 weeks, then gradually flattened out. The next 25% of patients underwent surgery within the following 7 weeks, 90% of patients had undergone surgery at 26 weeks, and the last 10% waited 27 to 39 weeks for their operation. In a series of univariate analyses, we studied access to surgery by gender, age, surgical procedure and priority class.

Access to surgery by gender and age

There were no differences in access to surgery between genders as measured by the log-rank test, $p = 0.94$, and Wilcoxon test, $p = 0.81$. This is consistent with the fact that proportions of urgent cases were almost equal in males (41%) and females (43%). Overall, the differences in access to surgery between age groups were statistically significant as measured by both the log-rank test, $p < 0.001$, and Wilcoxon test, $p = 0.002$ (Fig. 2). The case-mix analysis suggests that uneven distributions of diseases across age groups could account for these differences. For instance, the majority of those under 45 years of age were ranked as the least urgent cases, accounting for remarkably low access function compared with the other age groups. On the other hand, there were no differences in access to surgery between the 2 oldest age groups in which the proportions of most urgent cases were almost equal (data not shown).

Access to surgery by procedure

Differences in access to surgery were statistically significant among procedures as measured by the log-rank test, $p < 0.001$, and Wilcoxon test, $p < 0.001$. Fig. 3 shows that the shape of time-to-treatment curves also varied from among procedures. The proportion of patients receiving CAD was 22% at 4 weeks, 50% at 9 weeks, 75% at 22 weeks and 90% at 30 weeks. The proportion of patients receiving AAA repair was always higher than that for CAD, reaching 99% at 30 weeks. Access to surgery for PVD changed remarkably with time spent on the list. The time-to-treatment curve rose rapidly during the first 5 weeks, then gradually flattened out, becoming lower than the access function for AAA repair after the 15 weeks and approaching the access function for CAD.

Access to surgery by priority class

Priority class was a major factor influencing access to treatment. The differences in access to surgery between priority classes were statistically significant as measured by both the log-rank test, $p < 0.001$, and Wilcoxon test, $p < 0.001$ (Fig. 4). The graph suggests that there are 2 distinctive waiting periods for each priority class. The time-to-treatment curves rise rapidly during the initial period and then gradually flatten out. In priority class 1, the proportion of patients who received surgery was 90% at 4 weeks, but the last 10% received surgery during the following 12 weeks. Access to treatment decreased after 10 weeks on the waiting list in class 2, after 13 weeks in class 3 and 15 weeks in class 4. The proportion of

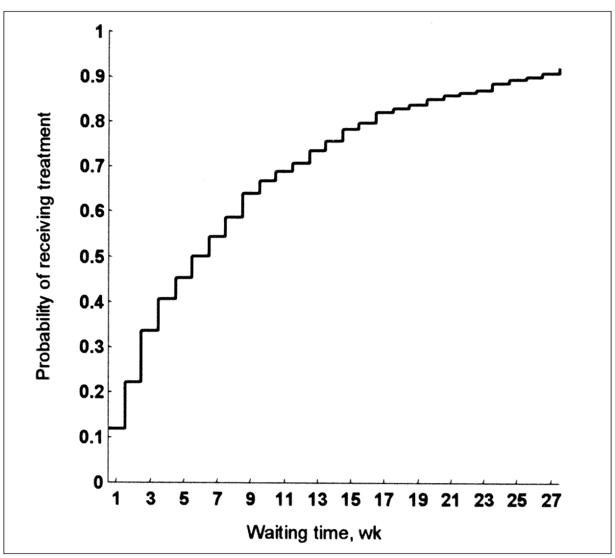

Fig. 1: Access to surgery as a function of waiting time.

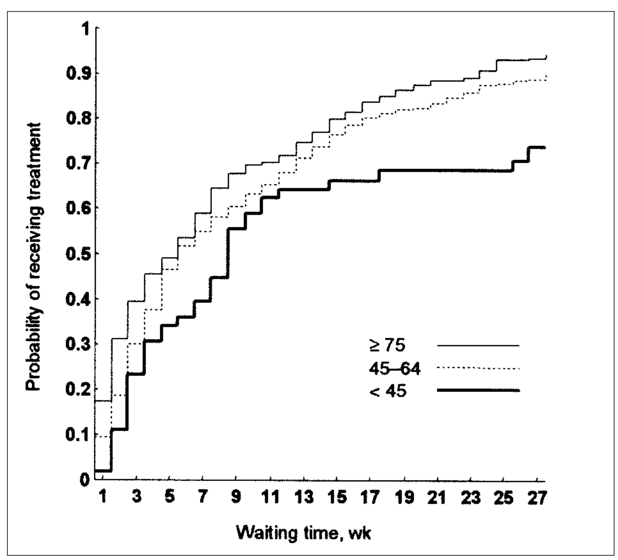

Fig. 2: Access to surgery by age.

patients who underwent operation within recommended time was 52%, 50%, 35% and 20%, respectively. The last 10% of patients waited 5 to 16 weeks, 10 to 16 weeks, 16 to 37 weeks, and 25 to 39 weeks in classes 1, 2, 3 and 4, respectively.

Fig. 5 shows the access functions for surgical procedures within priority class 5 (the least urgent case). There were significant differences in access to surgery by procedure as measured by the log-rank test, $p < 0.001$, and the Wilcoxon test, $p < 0.001$. Median waiting times between acceptance on the waiting list and treatment were 7, 10 and 19 weeks for AVF and PVD procedures and CAD, respectively. The access function for AVF patients rose faster than those for patients who needed CAD and PVD surgery. The proportion of AVF patients who underwent operation was 70% at 10 weeks, compared with 25 weeks for the other 2 procedures. The access function for PVD patients in priority class 5 repeated the pattern noted in Fig. 3. It rose initially at almost the same rate as the AVF function during the first 4 weeks, then flattened out, approaching CAD function by 25th week.

Waiting-time characteristics

Overall, the mean (and standard error of the mean) length of time between acceptance on the waiting list and admission for surgery was 10.2 (0.3) weeks and the median time was 7 weeks among patients added to the waiting list from 1994 to 1998. The mean waiting time was shortest for patients added to the list in 1996, 9.1 (0.7) weeks, and longest for patients added in 1995, 11.1 (0.7) weeks. Table 2 summarizes important statistical characteristics of waiting-time distributions by gender, age, procedure and priority class. The mean and median time estimates were virtually the same for males and females. However, there was considerable variation in the mean time according to age, from 15.8 (2.0)

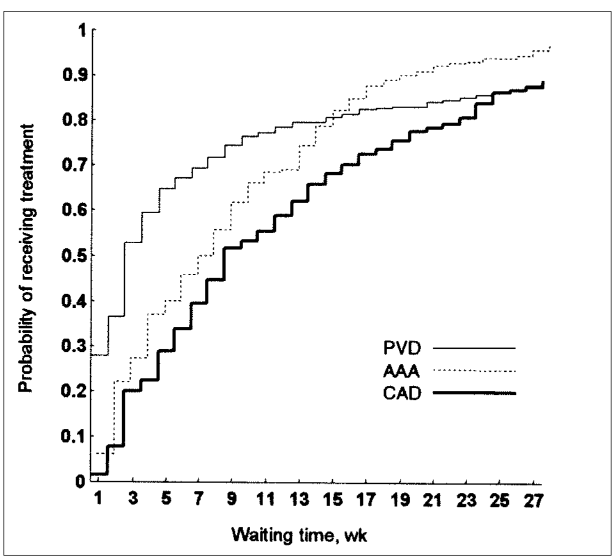

Fig. 3: Access to surgery by surgical procedure.

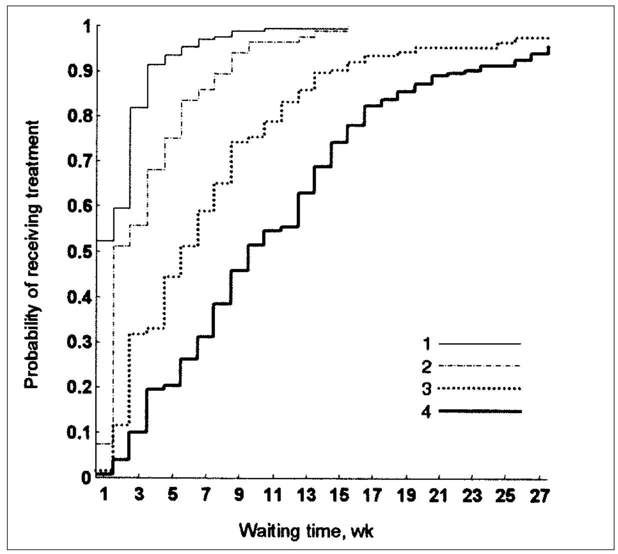

Fig. 4: Access to surgery by priority class.

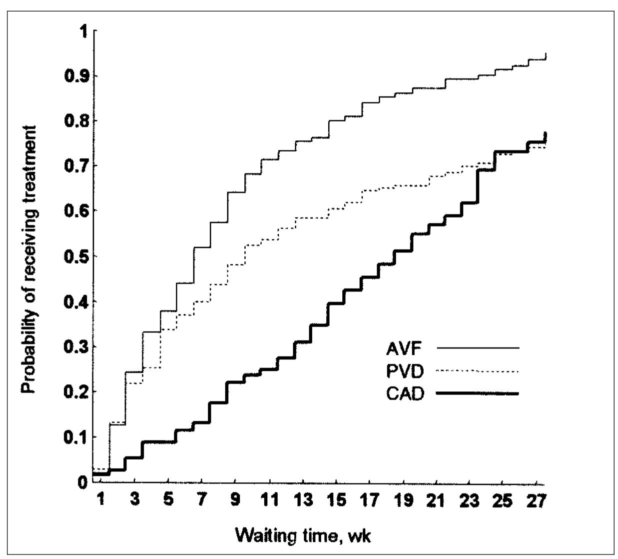

Fig. 5: Access to surgery in priority class 5, by procedure.

weeks (median 9 weeks) for those under 45 years, to 9.1 (0.6) weeks (median 6 weeks) for those aged 75 years and older. Median waiting times were 3, 7 and 9 weeks for PVD, AAA and CAD procedures, respectively. There was also a remarkable gradient in the mean waiting time across priority classes, being 85% shorter for the most urgent class (2.3 [0.1] weeks) compared with the least urgent (14.9 [0.6] weeks).

Admission rates

Overall, the mean number of admissions was 9.8 (0.3) per 100 patients each week. This rate did not vary considerably across different years. It was 8.9 (0.6) in 1995 and 11 (0.8) in 1996. Table 3 lists the mean admission rates by procedure and priority class. The lowest rate was observed for CAD, 7.4 (0.5), the highest — for PVD surgery, 11.5 (0.6). There was a significant gradient in the average admission rate across classes, with 42.1 (0.3) per 100 patients per week in class 1 and 6.4 (0.3) in class 5. Crude rate ratios (RR) associated with priority class were calculated relative to class 5. The admission rate was 7 times higher for class 1, RR = 6.6 (95%CI:5.5 to 7.8) and only 30% higher for class 4, RR = 1.3 (95% CI: 1.1 to 1.5). Table 4 shows test statistics and *p* values for the null hypothesis that the admission rate is constant over the time spent on the waiting list. This hypothesis is rejected for every priority class, indicating that the weekly admission rates were not constant. Fig. 6 also supports the conclusion that there is a variation in admission rates over time in every priority class.

Table 3: The mean (and SEM) weekly admission by surgical procedure and priority class rates for patients on the waiting list for elective vascular surgery

Characteristic	Admission rate*	Relative rate (95% CI)
Surgical procedure		
AAA repair	10.7 (0.6)	1.1 (0.9–1.3)
CAD	7.4 (0.5)	0.7 (0.6–0.9)
PVD surgery	11.5 (0.6)	1.2 (1.1–1.5)
AVF for hemodialysis	9.9 (0.9)	1.0
Priority class		
1 (most urgent)	42.1 (0.3)	6.6 (5.5–7.8)
2	24.7 (0.3)	3.9 (3.1–4.9)
3	12.5 (0.1)	1.9 (1.6–2.4)
4	8.1 (0.6)	1.3 (1.1–1.5)
5 (least urgent)	6.4 (0.3)	1.0

*No. of patients admitted per 100 patients per week.
AAA = abdominal aortic aneurysm, CAD = carotid endarterectomy, PVD = peripheral vascular disease, AVF = arteriovenous fistula.

Table 2: Distribution of waiting-times for vascular surgery by gender, age, surgical procedure and priority class

Characteristic	No. of patients	Removed from list, %	Waiting times, wk				
			Mean (and SEM)	Median	95% CI	Q1–Q3	Maximum
Gender							
Females	352	11.1	10.3 (0.6)	7	5–8	3–14	40
Males	732	8.2	10.1 (0.4)	6	6–7	3–14	44
Age group							
< 45	56	19.6	15.8 (2.0)	9	7–12	4–35	40
45–64	287	8.4	10.9 (0.7)	6	5–8	3–15	44
65–74	448	7.8	9.7 (0.4)	7	6–8	3–13	39
≥ 75	293	9.9	9.1 (0.6)	6	4–7	2–14	43
Surgical procedure							
AAA repair	311	6.8	9.2 (0.5)	7	6–8	3–14	39
CAD	264	10.2	13.0 (0.6)	9	8–12	5–19	38
PVD surgery	360	10.0	8.9 (0.6)	3	3–4	1–10	44
AVF for hemodialysis	149	10.1	10.0 (0.7)	7	6–9	4–13	37
Priority class							
1 (most urgent)	205	4.4	2.3 (0.1)	1	1–2	1–3	16
2	95	5.3	4.1 (0.3)	2	2–4	2–5	16
3	149	4.7	8.0 (0.6)	6	5–7	3–10	37
4	203	7.9	12.1 (0.6)	10	9–13	6–16	39
5 (least urgent)	432	14.4	14.9 (0.6)	10	9–13	5–24	44

Q = quartile, AAA = abdominal aortic aneurysm, CAD = carotid endarterectomy, PVD = peripheral vascular disease, AVF = arteriovenous fistula.

Discussion

Variation in waiting times is most fully described by the probability distribution function.[17] In health services research, where interest lies in describing how quickly patients receive service, the primary object for analysis is the access function, which shows the proportion of patients with waiting time less than some stated value. Whereas access functions express the cumulative effects of factors that affect access to services, the admission rate (the average number of admissions from a waiting list) is useful in describing the way in which the chances of admission change with time.

Table 4: Testing that admission rates are constant over time by priority class for patients on the waiting list for elective vascular surgery

Priority class	χ^2	*p* value
1	61.5	< 0.001
2	63.2	< 0.001
3	57.3	< 0.001
4	321.5	< 0.001
5	19.8	< 0.001

Instead of queuing theory, which uses mathematical analysis to determine the shape of a waiting-time distribution,[19] we used time-to-event analysis and

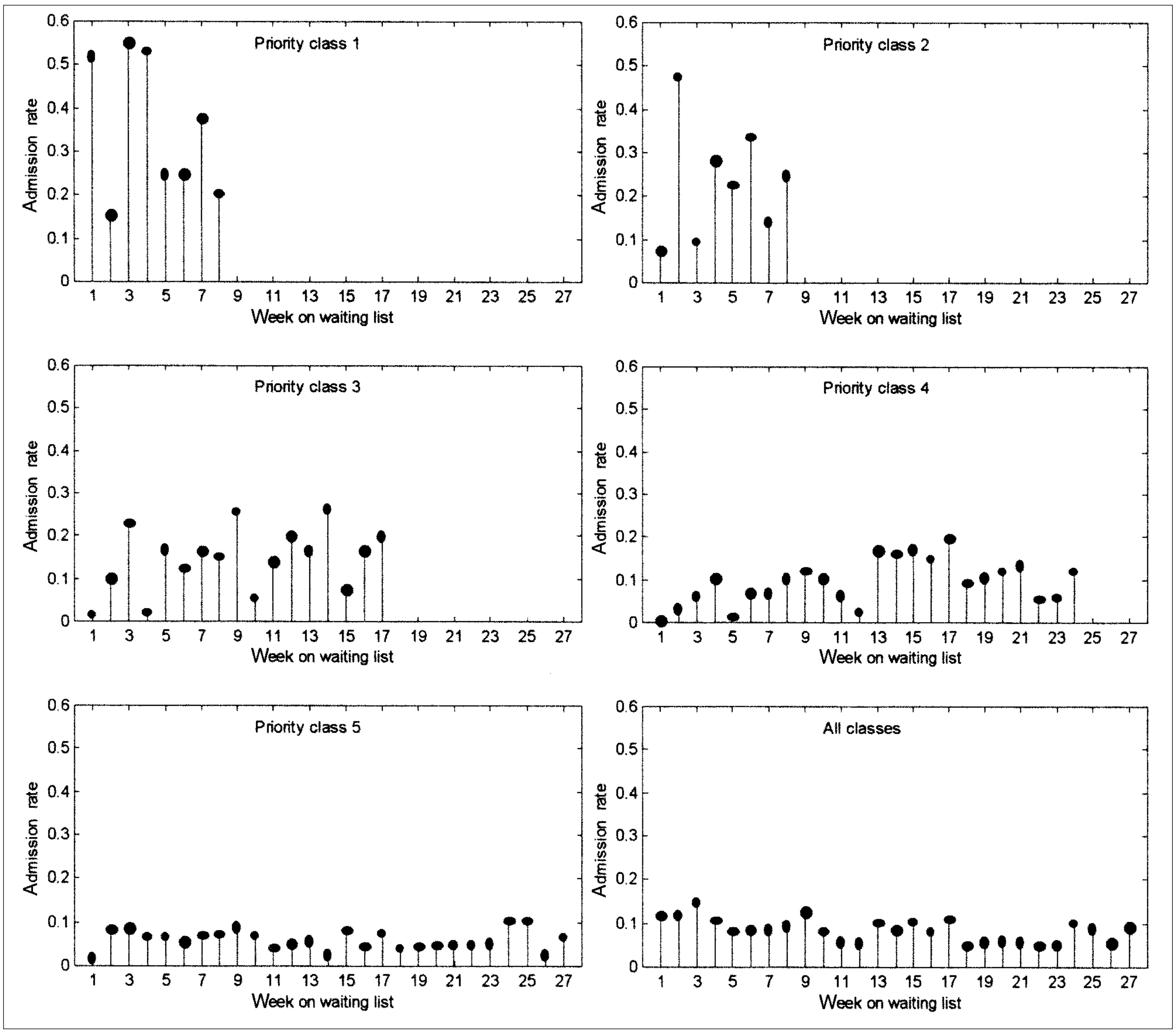

Fig. 6: Admission rate as a function of waiting time, by priority class.

estimated waiting-time distributions and admission rates based on observed data.[17] Waiting-time analysis, however, does raise some methodologic complications. These include the definition of the term "waiting time," the design of the data collection, and the selection of methods to deal with incomplete and correlated observations.

Waiting time refers to the interval between the time a surgeon accepts a patient for surgery and the time the hospital is ready to provide the service. The date of acceptance on the waiting list is clearly the appropriate point of time at which the waiting period starts. Other dates, such as the last visit to a specialist, are normally used as proxies only when data on dates of addition to the waiting list are not available.[7,9] The majority of previous studies used the surgery date to denote the end of the waiting period, either because of study design (where only those patients who underwent surgery were eligible for a study) or data availability.[5,7,9] However, we believe that date of admission rather than date of operation better characterizes the end of the waiting experience since time spent on a waiting list is technically the time to admission for surgery. This is particularly true since the time between admission and the actual operation can vary among procedures. In addition, more than 1 operation can take place for the same admission. Even though the operations have been done on different days, waiting was over on the date of admission. To compute the duration of time, we have to define the unit of time we are using, as well as the start and the end of the time period. Because a patient could be booked and admitted for elective surgery only through the waiting list, which is updated on a weekly basis, weeks spent on the waiting list serve as the natural counting unit of time for the purpose of describing the waiting period. For those removed from the list without surgery, the number of weeks to the date of removal was used.

In waiting-time analysis, retrospective and prospective approaches to data collection do not yield the same information. In retrospective design, the sampling unit is "patient received service" and waiting time is ascertained retrospectively, from the date of service to some preceding point. In prospective design, where waiting is evaluated in a cohort of patients followed forward in time from the date they were accepted on a waiting list, the sampling unit is "patient added to the waiting list." If every wait ended in receiving services, the 2 designs would generate equivalent data. However, the patients removed from the list without undergoing surgery would not be sampled in a retrospective waiting-time study. It has been suggested, in other time-to-event studies, that retrospective design can cause serious problems in drawing inferences.[20] For instance, coexisting illnesses could cause delay in surgery in a subpopulation and have no effect on the remainder. If sicker patients are routinely removed from the waiting list before surgery, the impact of comorbid conditions could potentially be missed by such a design. For these reasons, in our study, we chose to report waiting times collected prospectively.

Waiting-time data present themselves in a way that creates special problems in statistical analysis. One distinguishing feature of the data is that, at the time of removal from the waiting list, surgery will probably not be provided for all patients. In prospective studies, for those removed without receiving surgery the observation is considered as "right censored," indicating that the waiting time was less than it otherwise would be. In our study, almost 10% of patients added to the waiting list did not undergo surgery. Some of these patients experienced other competing events, such as deterioration in health, which caused them to be removed from the study (41 patients). Some of them were removed from the list before operation for reasons unrelated to waiting-time management; for example, the patient decided against surgery or the patient's condition improved (44 patients). Waiting time was only partially observable for a small fraction of patients studied because the study itself was restricted by date. The study period was limited, and patients added to the waiting list near the end of that period were still on the list at the end of the study, and all we knew was that their time to admission exceeded the observed value (14 patients).

If the censored observations are not accounted for, as in a retrospective design, the estimated probabilities of receiving the service may be biased toward a higher rate, and the median and mean waiting times may be underestimated. Regular statistical methods such as *t*-test, analysis of variance or regression analysis cannot cope with such a bias. In this analysis, we used a specialized set of statistical methods developed for handling such data.[21] A fundamental assumption of these methods is that the distribution of censored times does not depend on the parameters governing waiting-times distribution. If, however, censoring were related to the mechanism governing admissions, this assumption would have resulted in the biased estimate of the access function.

Several waiting times related to the same patient might be considered as possibly correlated observations. In our study, out of 974 patients accepted for surgery, 872 were added to the waiting list once, and 102 were added 2 or 3 times. Ten patients were reinstated after the cancellation of booked surgery, the remaining entered the list several times for different procedures. Correlation between observations may cause some distortion in estimates and hypotheses testing. To deal with it, one could develop the model of the joint distribution of the 2 waiting times.[22] Alternatively, the model could be fitted through the generalized estimation equations.[23] The resolution of this problem has been left for further study.

In this study, considerable variation in waiting times was observed in a queue for elective vascular surgery provided by 1 team of specialists. Although the average weekly admission rate was 10%, the proportion of patients who underwent surgery was 40% at 4 weeks, 50% at 7 weeks, 75% at 14 weeks, 90% at 26 weeks; the last 10% waited 27 to 39 weeks.

Prioritization according to surgical needs and severity of condition resulted in statistically significant differences in access to surgery among 5 priority classes, with a remarkable gradient in the average weekly admission rate from 42% in class 1 to 6% in class 5. Within any priority class, however, the admission rate was not constant over time: the access function rose rapidly during initial period, then gradually flattened out. Whereas the proportion of patients who underwent surgery within recommended times was 52%, 50%, 35% and 20%, the last 10% waited 5 to 16 weeks, 10 to 16 weeks, 16 to 37 weeks, and 25 to 39 weeks in classes 1, 2, 3 and 4, respectively.

Among the least urgent cases (class 5), there were statistically significant differences in waiting time by surgical procedure. Median times from acceptance to admission were 7, 10 and 19 weeks for AVF, PVD and CAD procedures, respectively. The access function for AVF patients rose faster than those for patients who needed CAD and PVD surgery. The access function for patients having PVD rose initially at almost the same rate as the AVF function, then flattened out, approaching the rate of the CAD function.

These variations of waiting times within priority classes suggest that urgency of intervention is not the only factor influencing time spent in a queue for elective surgery. First, if OR time becomes available unexpectedly, the surgeons occasionally call their waiting-list managers to see if there is anyone on the list who can come in within a few hours, especially if it is for a procedure requiring no preparatory work-up. Therefore, partitioning a queue according to patient agreement to come at very short notice may have changed the first-come-first-served queue discipline within priority classes in favour of that procedure. Second, we hypothesize that 2 events — delay in scheduling operations and cancellation of booked operations — may also change waiting times. Clearly, coexisting illnesses, a patient's request to postpone the operation or a surgeon's decision to ask for additional examinations before the scheduling could extend waiting times. On the other hand, cancellations because of lack of a hospital resource, such as an intensive care unit bed, could change queuing in favour of procedures that, for instance, would not require the resource.

Conclusions

Patients with equal surgical needs wait considerably differing times for access to elective surgery provided by the same team of specialists, where queuing procedures are uniform. It remains to be examined whether events related to the waiting-list management, for example, delays in scheduling operations and surgery cancellations, affect the waiting time after adjustment for urgency and comorbidity status.

Acknowledgement

Partial salary support for Dr. Sobolev came from the

Institute for Clinical Evaluative Sciences, Toronto.

References

1. Alter DA, Basinski AS, Naylor CD. A survey of provider experiences and perceptions of preferential access to cardiovascular care in Ontario, Canada. *Ann Intern Med* 1998;129(7):567-72.

2. Naylor CD, Sykora K, Jaglal SB, Jefferson S. Waiting for coronary artery bypass surgery: population-based study of 8517 consecutive patients in Ontario, Canada. The Steering Committee of the Adult Cardiac Care Network of Ontario. *Lancet* 1995;346(8990):1605-9.

3. *Reporting health performance: elective procedures waiting times in Nova Scotia, 1992–1996*. Halifax: Nova Scotia Department of Health; 1996. p. 1-30.

4. Dowling B. Effect of fundholding on waiting times: database study. *BMJ* 1997;315(7103):290-2.

5. Clover KA, Dobbins TA, Smyth TJ, Sanson-Fisher RW. Factors associated with waiting time for surgery. *Med J Aust* 1998;169(9):464-8.

6. *1998 Wait list report*. Victoria: British Columbia Ministry of Health and Ministry Responsible for Seniors; 1998. p. 1-40.

7. DeCoster C, Carriere KC, Peterson S, Walld R, MacWilliam L. Waiting times for surgical procedures. *Med Care* 1999;37(6 Suppl):JS187-205.

8. Shaw RA, Shortt SE. *Waiting for surgery at the Kingston General Hospital. Technical report*. Kingston: Queen's Health Policy Research Unit; 1999. p. 1-48.

9. Alter DA, Naylor CD, Austin P, Tu JV. Effects of socioeconomic status on access to invasive cardiac procedures and on mortality after acute myocardial infarction. *N Engl J Med* 1999;341:1359-67.

10. Alter DA, Basinski AS, Cohen EA, Naylor CD. Fairness in the coronary angiography queue. *CMAJ* 1999;161(7):813-7.

11. Pell JP, Pell AC, Norrie J, Ford I, Cobbe SM. Effect of socioeconomic deprivation on waiting time for cardiac surgery: retrospective cohort study. *BMJ* 2000;320:15-9.

12. Sobolev BG, Brown P, Zelt D. *Time spent on the waiting list for elective vascular surgery at the KGH. Technical report*. Kingston: Queen's Health Policy Research Unit; 1999. p. 1-57.

13. *Canadian classification of diagnostic, therapeutic, and surgical procedures*. 2nd printing. Ottawa: Statistics Canada; 1986.

14. *International classification of diseases*. 9th rev. Geneva: World Health Organization; 1978.

15. Guirguis EM, Barber GG. The natural history of abdominal aortic aneurysms. *Am J Surg* 1991;162(5): 481-3.

16. Sarin S, Shields DA, Farrah J, Scurr JH, Coleridge-Smith PD. Does venous function deteriorate in patients waiting for varicose vein surgery? *J R Soc Med* 1993; 86(1):21-3.

17. Hosmer DW, Lemeshow S. *Applied survival analysis: regression modeling of time to event data*. New York: John Wiley & Sons; 1999. p. 27-86.

18. Kalbfleisch JD, Prentice RL. *The statistical analysis of failure time data*. New York: John Wiley & Sons; 1980.

19. Gross D, Harris C. *Fundamentals of queueing theory*. 3rd ed. New York: John Wiley & Sons; 1998.

20. Weinberg CR, Baird DD, Rowland AS. Pitfalls inherent in retrospective time-to-event studies: the example of time to pregnancy. *Stat Med* 1993;12(9):867-79.

21. Klein JP, Moeschberger ML. *Survival analysis: techniques for censored and truncated data*. New York: Springer; 1997. p. 55-82.

22. Scheike T, Jensen TK. A discrete survival model with random effects: an application to time to pregnancy. *Biometrics* 1997;53:318-29.

23. Diggle PJ, Liang K, Zeger SL. *Analysis of longitudinal data*. Oxford (UK): Oxford University Press; 1994.

Reprint requests to: Dr. Boris Sobolev, Queen's University, 3rd Floor, Abramsky Hall, Kingston ON K7L 3N6; fax 613 533-6353; bs9@post.queensu.ca