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Improving the preoperative assessment clinic

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Chapter 4

Simulation to analyse planning difficulties at the preoperative assessment clinic

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Abstract

Background: Little research has been performed on designing appointment systems for the preoperative assessment clinic (PAC). We aimed to investigate how two organizational planning difficulties, (i) long access times and (ii) long waiting times, could be analysed systematically.

Methods: Two simulation models were used to test different scenarios to reduce access time and waiting times. First, we determined the number of appointments needed to reduce the access time from 5 weeks to 10 working days for 95% of all patients. Subsequently, we determined how long the consultation time should be, taking patients' American Society Anesthesiologists (ASA) physical status into account, to reduce the maximum waiting time to 10 min for 95% of all patients.

Results: Although we found the actual capacity, that is, consultations per day, to be enough to meet demand, a backlog existed, as the access time for the PAC was 5 weeks. A temporary extra capacity is needed to eliminate this backlog. When the reserved consultation time is 18 min for patients with ASA class I or II and 30 min for patients with ASA class III or IV, the maximum waiting times decrease to 10 min for 95% of all patients.

Conclusions: This study shows that a simulation model is a helpful tool to determine the capacity needed to achieve and to maintain a proposed service level for access times and waiting times. In addition, waiting times at the PAC can be reduced by making the reserved consultation time dependent on patients' ASA physical status.

In the Netherlands, as in other Western countries, the demands on health-care services are growing. Concurrently, stakeholders of the health-care system (governments, health-care insurance companies, and patients) are increasingly demanding transparent outcome measures and tools to compare similar health-care services in different hospitals with regard to quality, cost-efficiency, and service levels. In recent years, the preoperative assessment clinic (PAC) has been implemented in the organizational structure of most major hospitals.[1] Although some aspects of the PAC have been investigated, such as preoperative laboratory and diagnostic testing,[2;3] patient satisfaction,[4] and staffing of the outpatient clinic,[5;6] research performed on scheduling is limited.

The science of scheduling and queuing is complex. Operational Research (OR), a science that arose during World War II to improve logistics, uses mathematical modelling, queuing theory, and simulation to aid decision-making in complex problems concerning coordination and execution of operations within an organization. OR has spread from the military to the industry, for example the health-care industry. Modelling is a cornerstone of health OR and has many applications, including appointment systems and waiting lines management.[7] Bailey and Welch[8-10] pioneered the study of outpatient clinic scheduling. Since then, other research has been done in this area.[11-18]

Dexter[16] gave an overview of the science of clinic scheduling that can be applied to the PAC. He stated that an improperly designed appointment system is the main reason for long patient waiting times at the PAC, next to the large standard deviation of consultation times, provider tardiness, lack of patient punctuality, and patient no-shows.

A well-designed appointment system, with decreased access and waiting times, will significantly increase the service level of a PAC and patient satisfaction.[4;16] Hence, in this study, we aimed to investigate how two organizational planning difficulties could be analyzed systematically: (i) the long access times, that is, the time between making an appointment and the consultation taking place; and (ii) the long waiting times, that is the time between the patient's appointment time and the start of the consultation. For this purpose, two simulation models were validated for

the PAC and subsequently different scenarios were tested to reduce the access time and the waiting times.

Methods

Hospital setting and current planning

This study was performed at the Academic Medical Centre, Amsterdam, the Netherlands, a large tertiary care university hospital. Annually, 12 000 patients are assessed at the PAC. The PAC is opened 5 days a week; opening hours are from 8 a.m. to noon and from 1 p.m. to 4:30 p.m. However, clinic sessions are booked till approximately 3:00 p.m. because of the anticipated accumulation of waiting times. Patients are first seen by a nurse (there are two nurses full time/day available) and subsequently all patients are seen by a physician (either a resident or an anaesthetist). At the time of scheduling, it is unknown how many physicians will be available; there are either two or three physicians working at the PAC per day. Irrespective of the number of physicians, only two clinic sessions are scheduled; physicians do not have their own programme.

From a logistic point of view, there are three different groups of patients: (i) regularly scheduled patients, (ii) semi-urgent patients needed to be seen within several days, and (iii) patients without an appointment, the so-called 'walk-in' patients. Walk-in patients are elective patients who live far from the hospital (>50 km). Elective patients who are healthy, American Society of Anesthesiologists' (ASA) I, might walk in if there are not too many patients waiting (no strict criteria). Beforehand, it is not known how many patients will walk-in on a daily basis. Though advisable, currently no time is reserved for this last group and they have to be seen additionally, in between appointments.

The foremost logistical problems within our PAC are the long access time and the long waiting times. These two problems and their analysis were handled separately, using two different simulation models. First, we determined how many appointments are needed per week to reduce the access time. Secondly, we determined how much time should be reserved per consultation, taking patients' ASA physical status into account.

Reducing the access time

At the start of our research, the access time for regularly scheduled patients was 5 weeks. It is uncertain whether this backlog arose due to decreased capacity or increased demand in the past or a combination of both. It is obvious that more patients need to be seen a day to eliminate this 5 week backlog. However, when taking randomness into account, establishing the number of patients needed to be seen per day is not so straightforward. Consultations are not equally spread over the week, but differ during the week. As one consultation less than the optimal number can make the difference between achieving a service level or not, a global calculation will not suffice. Therefore, we used a simulation model to determine in detail the necessary capacity, that is, the number of consultations per day. Apart from the capacity needed to eliminate the backlog and reduce the access time to 10 working days, we also calculated the necessary capacity to maintain this service level for 95% of all patients who require an appointment. In contrast to the current situation, we took walk-in patients into account and reserved extra capacity for this group. The number of consultations needed for walk-in patients was based on a 95% range determined by historical data from 2005. The simulation model was only used for the two clinic sessions that are scheduled, that is, regular and semi-urgent patients.

Recently, a discrete event simulation model was developed at our university hospital to analyse appointment-based scheduling at outpatient departments.[19] This simulation model is based on a single queuing model; it handles an outpatient department as one service station and assumes there is only one waiting row (patients with an appointment waiting for access). Because patients arrive at random and independently of each other, a Poisson distribution is used to simulate the arrival process. When a patient requests an appointment, the model checks the schedule for the first available appointment. For every patient, the same fixed consultation time is reserved. There are two input parameters: the demand per specific working day and the complete weekly schedule, which describes the total number of reserved consultations per working day and the number of physicians available per clinic session. After the simulation model has determined the appointment date and time, the patient waits until the consultation takes place. The

time the patient is waiting between making the appointment and the consultation taking place is referred to as access time. The simulation model will generate the mean and 95th percentile of the access time. Both output parameters are generated every time a patient leaves the system, enabling the analysis of the access time over time. The model can handle one demand stream at a time; so to analyse different patient groups, the model has to be used several times. In the current schedule, capacity is reserved for each patient group, so the model fits the present situation.

Because the process of appointment-based scheduling at the PAC is the same as described above, we validated and used the simulation model for the PAC (Appendix 1). The input parameters for our model, the mean number of consultations requested per day (demand), and the current capacity per working day were based on historical data from 2005.

After determining the temporary capacity to eliminate the backlog of 5 weeks and the permanent capacity to maintain an access time of 10 working days for 95% of all patients, we examined the possibility to benefit from a decreased fluctuation in demand by grouping the two logistical groups (regular and semi-urgent patients). Since the minimum required capacity depends on the fluctuation in demand, grouping the two logistical groups could lead to a decreased fluctuation in demand and therefore to a reduced required capacity.

Reducing the waiting times in the waiting room

In the second part of our study, we analysed the possibilities to reduce the waiting times. Increasing the time reserved for a consultation would obviously reduce the waiting times. In order to find the optimal consultation time, at which neither the patient nor the physician has to wait too long, we used a simulation model (Appendix 2).

Before patients' appointment at the PAC, they have to complete a health questionnaire. With this questionnaire, it is possible for a clerk to make a good estimation of patients' ASA physical status. Patients' ASA physical status gives a fair indication of the consultation time needed.[6] In the current schedule, 15 min are

reserved for all patients irrespective of their ASA physical status. In a previous study, we found that patients frequently had to wait, sometimes over an hour, because earlier consultations exceeded the reserved consultation time.[20] We hypothesized that waiting times could be reduced by adapting the consultation time to patients' ASA physical status. This was analysed with another simulation model.

In contrast to the first model, the second simulation model does not take the appointment-based scheduling into account, but looks at the operational process on a daily basis. Patients arrive around the appointed time (some may be late) and wait until a physician calls them in. After their consultation, patients leave the PAC. This too is a single queuing model with one waiting row (the patients in the waiting room) and one service station (the PAC).

The simulation model contains a stochastic distribution that determines if a patient has ASA physical status I, II, III, or IV. This distribution is based on historical data from 1996 to 2005. After determining the ASA physical status, a triangular distribution is used to determine the actual consultation time for each patient. To do so, the calculated consultation time sometimes will exceed the reserved 15 min, which will result in waiting time for the next patient. The output of the simulation model is the mean and 95th percentile of the waiting time.

The current schedule, with a consultation time of 15 min for all patients, was used as initial input for the arrival process of the scheduled patients. The waiting time generated with the simulation model was compared with the waiting time measured in a previous study[20] in order to validate our model. Subsequently, by adapting the consultation times to patients' ASA physical status, different scenarios were tested to determine when the desired service level (maximum waiting time of 10 min for 95% of all patients) was attained, using the schedule obtained with the first simulation model as input.

Results

Reducing access time

Table 1. The median (25–75th percentile) demand, i.e. number of consultations requested/day, per logistic patient group in 2005

Patient group	Monday	Tuesday	Wednesday	Thursday	Friday
Regularly scheduled	20 (16-24)	27 (22-32)	21 (18-26)	24 (20-27)	13 (11-17)
Semi-urgent	17 (13-23)	23 (17-26)	16 (12-24)	19 (14-25)	17 (12-20)
Walk-in	5 (4-7)	8 (7-9)	4 (4-7)	5 (4-6)	5 (4-5)

Table 1 shows the demand for the three logistic groups in 2005 (regularly scheduled, semi-urgent, and walk-in). The access time (mean and 95th percentile), which might be achieved in the future, was obtained by simulation, based on retrospective data of the demand and capacity in 2005 (data not shown), is presented in Figure 1. This figure clearly illustrates that the number of consultations currently reserved for regular scheduled patients is sufficient to meet the aimed service level of 10 working days. Moreover, it shows that this service level can be
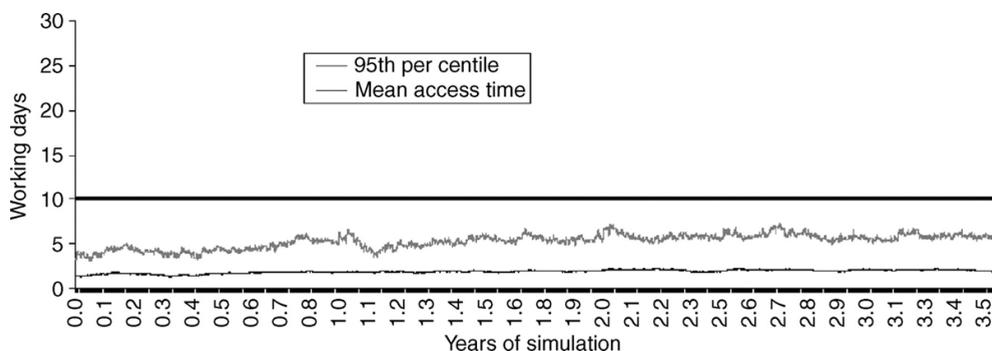
Fig 1 Part of the simulation period (3.5 yr) of the access time at the PAC for regularly scheduled patients according to capacity and demand in 2005. The aimed service level is a maximum access time of 10 working days for 95% of all patients (depicted as black horizontal line in the figure). PAC, preoperative assessment clinic.

A

B
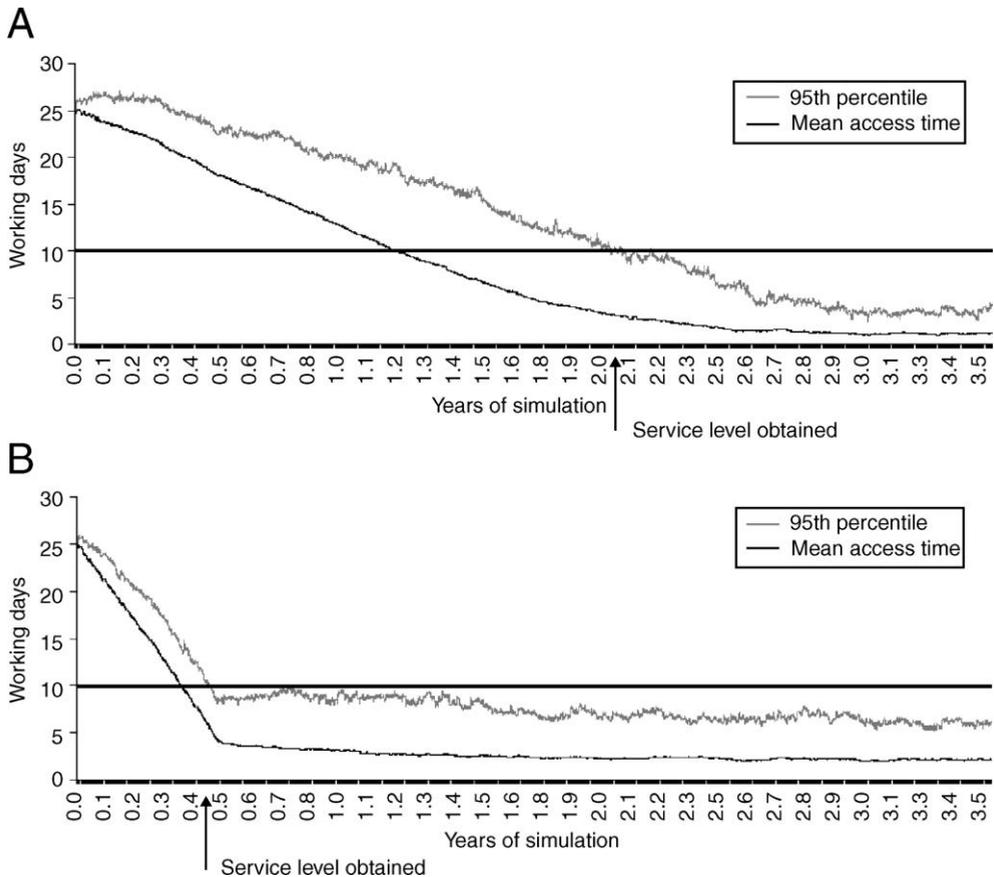
Fig 2 Part of the simulation period (3.5 yr) of the access time at the PAC for regularly scheduled patients. (A) The present situation according to capacity and demand in 2005, taking backlog into account. After approximately 2 yr, the aimed service level is attained. (B) By temporarily increasing the capacity with 16 consultations a week, the aimed service level is attained after 6 months. The aimed service level is a maximum access time of 10 working days for 95% of all patients (depicted as black horizontal line in the figure). PAC, preoperative assessment clinic.

maintained if the demand stays the same. Nevertheless, there is a backlog: the access time is 5 weeks. With the current capacity, it would take more than 2 yr to eliminate the backlog (Fig. 2A). To eliminate the backlog within 6 months, the capacity has to be increased by 16 consultations a week during this 6 month

period. Subsequently, the capacity can return to 112 consultations a week (Fig. 2B). The access time for semi-urgent patients is not allowed to be more than 10 working days; therefore, this logistic group has no backlog. The simulation model was used to evaluate more accurately the number of consultations necessary to meet the demand, namely 104 per week (data not shown).

When access times for regular and semi-urgent patients are both within 10 working days, it appeared to be no longer necessary to maintain the scheduling group 'semi urgent'. Grouping regular and semi-urgent patients together did not decrease the fluctuation in demand. Although combining the two groups did not reduce the required capacity, it simplifies the planning.

Finally, Table 2 gives an overview of the capacity that is needed to ensure the access time meets the desired service level.

Table 2. The capacity, i.e. number of consultations/day, needed to maintain an access time of 10 working days for 95% of all patients who require an appointment, and the temporary extra capacity (number between brackets) needed to eliminate a 5 week backlog within 6 months

	Capacity for regularly scheduled patients (temporary extra capacity)	Capacity for semi-urgent patients	Capacity for walk-in patients	Total capacity (temporary total capacity)
Monday	22 (3)	21	9	52 (55)
Tuesday	23 (4)	21	11	55 (59)
Wednesday	22 (3)	21	8	51 (54)
Thursday	23 (3)	21	10	54 (57)
Friday	22 (3)	20	7	49 (52)

Reducing waiting times in the waiting room

The median (25–75th percentile) consultation time as measured in 2005 was 10 (7–15) min for ASA class I patients (52%), 14 (10–19) min for ASA class II patients (31%), 17 (10–24) min for ASA class III patients (15%), and 21 (12–35) min for ASA class IV patients (2%). The current schedule (2005) and reserved consultation
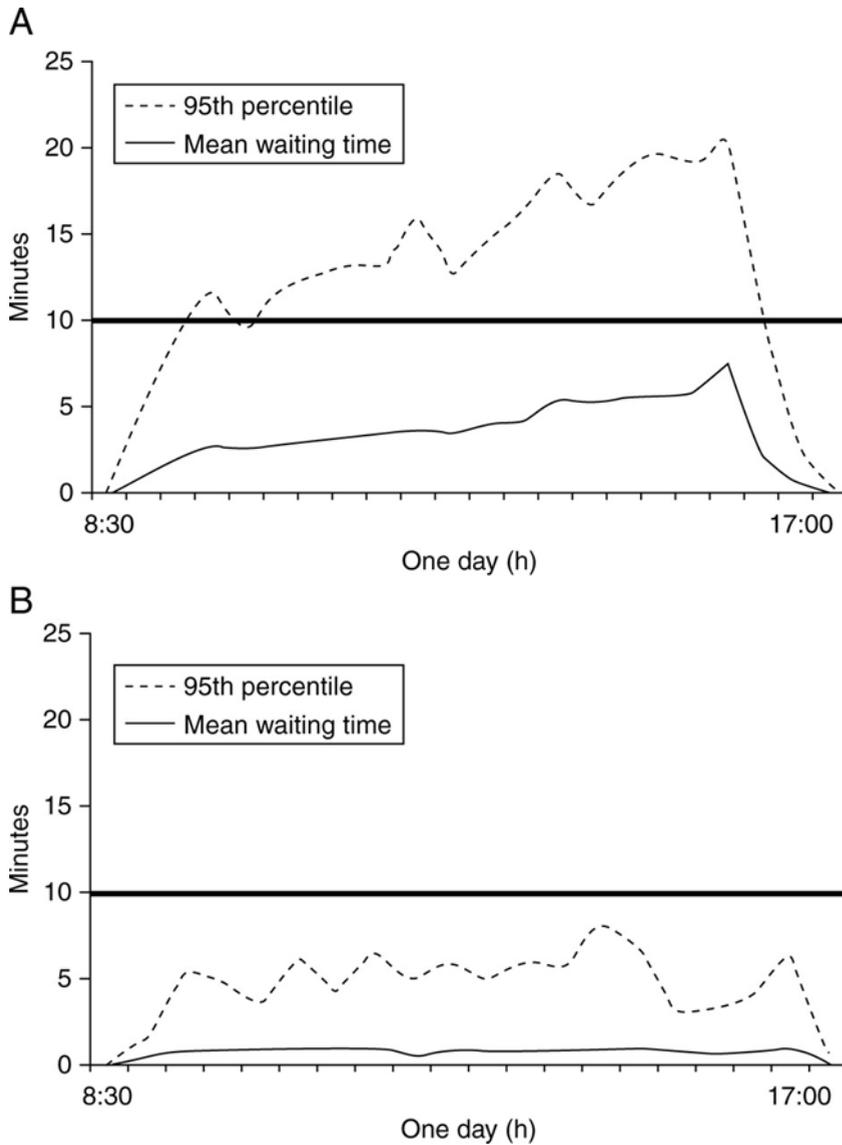
Fig 3 Simulation of the waiting time at the PAC with a reserved consultation time of (A) 15 min (one working day is shown) and (B) 18 min for patients with ASA class I or II and 30 min for patients with ASA class III or IV (one working day is shown). The aimed service level is a maximum waiting time of 10 min for 95% of all patients (depicted as black horizontal line in the figure). PAC, preoperative assessment clinic.

time of 15 min were used to simulate the current waiting times (Fig. 3A). The simulated waiting times were similar to those measured at the department. From this, we may conclude that the simulation model gives a satisfactory representation of the current situation and it can be used to investigate other scenarios.

In the simulation model, we first investigated the situation with a reserved consultation time of 30 min for patients with ASA class III or IV and 15 min for patients with ASA class I or II. As expected, the waiting times decreased; however, the aimed service level was still not achieved as the waiting time increased during the day (data not shown). To further reduce the waiting times, the reserved consultation time for patients with ASA physical status I or II had to be changed. When the reserved consultation time was increased from 15 to 18 min, the mean waiting time and the 95th percentile was less than 10 min (Fig. 3B). As a reserved consultation time of 18 min is not workable, an alternate reserved consultation time of 15 and 20 min can be used for ASA class I and II patients.

Table 3 The capacity, i.e. number of consultations/day, needed to maintain an access time of 10 working days or less and a maximum waiting time of 10 min for 95% of all patients, and the temporary extra capacity (number between brackets) needed to eliminate a 5 week backlog within 6 months, divided in ASA class I and II and III and IV, and walk-in patients. ASA, American Society of Anesthesiologists

	Capacity for ASA class I and II (temporary extra	Capacity for ASA class III and IV (temporary extra	Capacity for walk-in	Total capacity (temporary
Monday	36 (3)	7	9	52 (55)
Tuesday	36 (3)	8 (1)	11	55 (59)
Wednesday	36 (3)	7	8	51 (54)
Thursday	36 (3)	8	10	54 (57)
Friday	35 (3)	7	7	49 (52)

The analyses of the simulation studies have finally led to the capacity presented in Table 3. This table shows the amount of consultations per day and ASA class needed to fulfil the goal of seeing 95th of all patients within 10 min and having an

access time of 10 working days or less for 95% of all patients. To eliminate the existing backlog within 6 months, a temporary increase in the capacity is required, which is also presented in Table 3.

Discussion

In this study, we considered two organizational planning difficulties often encountered at a PAC: (i) long access times and (ii) long waiting times. With two different simulation models, validated for the PAC, we tested scenarios to reduce the access time and the waiting times, respectively. The main results show that only a temporary extra capacity is needed to reduce the access time. Furthermore, when making the reserved consultation time dependent on patients' ASA physical status, the waiting times can be reduced.

A simulation model provides an insight into the way a system operates and it can be used to predict the result of an intervention.[21;22] Simulation has been used in various fields of anaesthesiology.[23-25] Owing to the complexity of hospital organizations, implementing organizational changes is often difficult, time-consuming, and costly. By simulating an intervention, potentially unsuccessful changes can be prevented. We used a simulation model to determine the capacity needed to achieve and maintain our proposed service level for access time and waiting times. The desired service level might vary between institutions, but the input needed for the simulation model to calculate the capacity is the same, namely the mean demand per working day and the complete week schedule, specified for all patient groups.

There is a strong correlation between the time spent at the PAC and patient satisfaction.[4;16] A PAC with an appointment-based schedule will have a shorter average waiting time, because there is less variability in arrival times.[16;26-28] Principal causes for long waiting times in outpatient departments are provider tardiness, patients' unpunctuality, patient no-shows, and improperly designed appointment systems.[15;16] For efficient scheduling, it is imperative to know beforehand how many staff is available per day. This allows physicians to have their own schedule. A specific cause for long waiting times at PACs is the large standard deviation of the consultation time.[16] We considered this specific problem

of high variability of the consultation times. We found that more time was needed for the preoperative assessment when the patient's ASA class was higher.[6] Better matching of the reserved consultation time and the actual consultation time makes more efficient planning possible. By making the reserved consultation time dependent on a patient's ASA physical status, waiting times can be reduced without increasing the idle time,[16] that is, the time when the physician is not consulting because no patients are waiting to be seen.[15]

At our clinic, the preoperative assessment is only performed by anaesthetists and anaesthesiology residents. However, it is not uncommon in some countries for nurses or physician assistants to perform preoperative assessment.[3;6;29] Previous studies have shown that nurses are less accurate at preoperative assessment than anaesthetists;[6;29] therefore, it is debatable whether or not nurses should perform preoperative assessment. With good guidelines and under clear terms and conditions, it might be warranted, but further research is needed to clarify this. In clinics where nurses do preoperative assessment, this is often limited to ASA class I and II patients. By having patients fill in a health questionnaire before making an appointment, it is possible to make a good estimation of patients' ASA physical status. This can help direct patients to the appropriate caregiver, improving efficiency. It should be taken into account that likely more time needs to be reserved when nurses perform the consultation, as they need more time for the preoperative assessment than anaesthetists.[6]

In our study, we focused on improving the appointment system. A further reduction of the patient flow time might be attained by modifying the logistics of preoperative laboratory and diagnostic testing, but this was beyond the scope of this study. Two other principal causes for long patient waiting times are provider tardiness and patients' unpunctuality. All efforts should be made to ensure that clinic sessions start punctually and that patients arrive on time. Patients' punctuality is best when patients do not have a preceding appointment when visiting the PAC. [16] In addition, the schedule should contain enough slack time: a buffer against variations in the consultation time to prevent waiting time. By reducing the variation in the consultation times (e.g. by making the reserved consultation time dependent on

patients' ASA physical status), less slack time is needed to maintain the desired service level; making more efficient scheduling possible.[27]

We used two simulation models as means to attain improvement of the patient flow. The outcome should be assessed to see if the desired outcome has been achieved, for example, by measuring patient satisfaction. The Patient Experiences with the Preoperative Assessment Clinic (PEPAC) questionnaire[30] can be used to measure if improvement has been attained.

The results of our study have shown that a simulation model is a valuable tool to calculate the capacity needed to achieve and maintain a proposed service level for access time and waiting times. In addition, waiting times at the PAC can be reduced by making the reserved consultation time dependent on patients' ASA physical status. We will use the results of this study to redesign our appointment system.

Appendix 1

Algorithm of the scheduling of requests for consultations

1) Read in the schedule of physicians.

2) Read in the duration of the consultation sessions.

3) Scheduling of requests for a consultation (see text block).

4) Determine the mean access time and the 95th percentile.

NextEvent = Arrival

TimeNextArrival = 0

TimeNextScheduling = 0

TimeNextEvent = TimeNextArrival

repeat

    Clock = TimeNextEvent

    if change of day **then** day = day + 1

    if NextEvent = Arrival **then**

      begin

        Generate new request

        Put request in queue

        Number of arrivals = number of arrivals + 1

        Number of requests present = number of requests present + 1

        Determine TimeNextArrival of new request using a Poisson distribution

      end

    else

      if NextEvent = Scheduling **then**

        begin

          if Number of requests present > 0 **then**

            if Day ≠ holiday **then**

begin

Schedule first request in queue in first consultation available

Determine waiting time request

Request leaves the queue

Number of requests present = number of requests present - 1

Number of requests leaving the system = number of requests leaving the system + 1

end

TimeNextScheduling = current TimeNextscheduling + duration of a consultation session

end

if TimeNextArrival < TimeNextScheduling **then**

begin

NextEvent = Arrival

TimeNextEvent = TimeNextArrival

end

else

begin

NextEvent = Scheduling

TimeNextEvent = TimeNextScheduling

end

until Number of arrivals = N

Appendix 2

Algorithm of the simulation of the daily process

1) Read in the schedule of consultations.

2) Read in the duration of the consultation sessions.

3) Arriving process of patients (see text block).

4) Determine the mean waiting time and the 95th percentile.

NextEvent = Arrival

TimeNextArrival = 0

TimeNextConsultation = Begin of first consultation session > 0

TimeNextEvent = TimeNextArrival

repeat

    if NextEvent = Arrival **then**

      begin

        Generate new patient

        Determine ASA physical status

        Number of arrivals = number of arrivals + 1

        Number of patients present = number of patients present + 1

        Determine new TimeNextArrival of new patient according to the schedule of consultations

      end

    else

    if NextEvent = Consultation **then**

      begin

        Determine waiting time patient

        Determine duration of consultation according to a triangle distribution

        TimeNextConsultation = current TimeNextConsultation + duration of the consultation

        Patient leaves the outpatient department

Number of patients present = number of patients present - 1

Number of patients leaving the system = number of patients leaving the system + 1

end

if TimeNextArrival < TimeNextConsultation **then**

  begin

    NextEvent = Arrival

    TimeNextEvent = TimeNextArrival

  end

  else

  begin

    NextEvent = Consultation

    TimeNextEvent = TimeNextConsultation

  end

until Number of arrivals = N

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