

# Exploring the relation between process design and efficiency in high-volume cataract pathways from a lean thinking perspective

ELLEN J. VAN VLIET<sup>1</sup>, EELCO BREDENHOFF<sup>2</sup>, WALTER SERMEUS<sup>1</sup>, LUCAS M. KOP<sup>2</sup>, JOHANNES C.A. SOL<sup>3</sup> AND WIM H. VAN HARTEN<sup>2</sup>

<sup>1</sup>School of Public Health, Faculty of Medicine, Catholic University Leuven, Leuven, Belgium, <sup>2</sup>School of Management and Governance, University of Twente, Enschede, The Netherlands, and <sup>3</sup>World Association of Eye Hospitals, Rotterdam, The Netherlands

Address reprint requests to: Ellen Joan van Vliet, Centre for Health Services and Nursing Research, School of Public Health, Faculty of Medicine, Catholic University Leuven, Kapucijnenvoer 35, 4th floor, B-3000, Leuven, Belgium. Tel: +31-10-4023440; Fax: +31-10-4017755; E-mail: ellen.vanvliet@student.kuleuven.be

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## Abstract

**Objective.** To compare process designs of three high-volume cataract pathways in a lean thinking framework and to explore how efficiency in terms of lead times, hospital visits and costs is related to process design.

**Design.** International retrospective comparative benchmark study with a mixed-method design.

**Setting.** Three eye hospitals in the UK, the USA and the Netherlands participated in this study. All are major international tertiary care and training centres in ophthalmology.

**Participants.** Data on all patients who underwent first eye cataract surgery in 2006 were used.

**Interventions.** The study related six operational aspects of lean thinking in the process design to efficiency.

**Main outcome measures.** Measures of lean aspects were operational focus, autonomous work cell, physical lay-out of resources, multi-skilled team, pull planning and elimination of wastes. Efficiency was measured with lead times (access time plus waiting time for surgery), hospital visits and direct costs.

**Results.** Operational focus was influenced by external circumstances leading to different orientations on efficiency. Pull planning with integrating activities in one-stop procedures conducted by multi-skilled nurses as well as eliminating wastes reduced both the number of hospital visits and costs. Short lead times were associated with the use of a general outpatient clinic and a high-volume cataract surgery clinic.

**Conclusions.** The environmental context and operational focus primarily influenced process design of the cataract pathways. When pressed to further optimize their processes, hospitals can use these systematic benchmarking data to decrease the frequency of hospital visits, lead times and costs.

**Keywords:** lean management, benchmarking, process assessment, cataract

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## Introduction

Cataract, a clouding of the eye's lens, is the leading cause of curable blindness in the world [1]. Cataract surgery is the most frequently performed ophthalmic surgical procedure in many countries [2]. Today, limited access to cataract surgery in industrialized countries is mainly caused by outmoded and inefficient cataract pathways [3]. Despite substantial differences in cataract pathways, variations in patient outcomes are

small [4, 5]. As a result, cataract surgery as a whole can mainly be differentiated on how the cataract pathway is organized [6]. As cataract surgery is a high-volume, relatively low-complex procedure, it could benefit from applying industrial principles, such as lean thinking [6, 7].

Lean thinking, originally developed in Japan by the Toyota Motor Corporation since 1930, is a process-based management strategy that focuses on reducing lead times and costs by eliminating non-value added activities [8, 9]. Toyota gradually

developed multiple operational and sociotechnical tools to maximize resource use, flexibility and quality in their production system [10–12]. Sociotechnical aspects include difficult-to-imitate techniques to grow organizational capability, such as experimentation and building cross-functional teams [10, 13]. Operational aspects include more-transferable techniques to move products, or patients, through a series of operations, such as applying autonomous work cells, cross training and pull planning. To expedite flow of a variety of products, Toyota deviated from the concept of division of labour as applied in Henry Ford's assembly line and organized work in autonomous work cells, in which cross-functional multi-skilled teams, workstations and equipment are arranged in the processing sequence [8, 9, 12, 14]. To avoid bottlenecks or queues between operations, workers are trained to conduct multiple tasks interchangeably [9, 12]. Cross training also reduces the number of handoffs and associated risks on delays [14] and errors [15, 16]. Pull planning (e.g. the production system is driven by customer orders) connects succeeding operations to each other with the shortest lead time possible [8, 14]. In such a lean process design, all in-process inventory, waiting and transportation between operations becomes visible and can be eliminated [12, 14].

In contrast, most hospitals have fragmented care processes that are difficult to coordinate, resulting in delays or duplications of services [9, 16, 17]. To achieve both timely and efficient service, hospitals are shifting towards a more process-oriented organization [17]. To streamline care processes, several hospitals introduced lean thinking aspects and reported significant improvements in quality, efficiency and/or lead times [18–21].

The operational aspects of lean thinking can be used to construct a process-based framework to analyse the relation between process design and efficiency. The aim of this study is to compare process designs of three high-volume cataract pathways in such a lean framework and to explore how efficiency in terms of lead times, hospital visits and costs is related to process design.

## Methods

### Study design and study setting

An international retrospective comparative benchmark study with a mixed-method design was conducted to compare three cataract pathways of eye hospitals in (1) the United Kingdom (UK), (2) the United States of America (USA) and (3) the Netherlands (NL). All three hospitals are major international tertiary care and training centres in ophthalmology. They are large providers of eye care, with 260 000 outpatient visits and 24 000 surgical procedures per year in Hospital 1, 160 000 outpatient visits and 25 000 surgical procedures per year in Hospital 2 and 140 000 outpatient visits and 13 000 surgical procedures per year in Hospital 3.

A comparative benchmark study focuses upon how similar activities are organized by different organizations [22] and entails a comparison of the performance and underlying processes [23]. We restricted this comparative benchmark study of the cataract pathways to the period between referral to the

hospital and the first review after surgery. The study was based on data of all patients who underwent first eye cataract surgery in 2006. We used data on 9195 patients in Hospital 1, 8761 patients in Hospital 2 and 4093 patients in Hospital 3. All three hospitals provided written permission for data collection and dissemination of anonymous results of this benchmark study.

### Lean aspects in a cataract pathway

We identified eight activities in a standard cataract pathway, based upon best practice guidelines for cataract surgery [24–26] and expert interviews with a specialized cataract surgeon in Hospital 3 and two nurse managers in Hospital 1 and 2 (see Box 1). To systematically compare how these activities were organized, we constructed a lean framework (see Fig. 1). Despite the extensive literature available on lean thinking, for the purpose of this benchmark study we only included six basic operational aspects of lean thinking that highly impact process design (e.g. the delegation and coordination of activities), as described by Ohno [8], Womack and Jones [14] and Liker [12]: (1) operational focus; (2) autonomous work cell; (3) physical lay-out of resources; (4) multi-skilled team; (5) pull planning and (6) elimination of wastes.

- (i) Operational focus in a lean pathway is to 'reduce the time line by removing the non-value added wastes' [8]. The patient episode throughput time is minimized by improving patient flow through the care system and by eliminating non-value adding activities [27]. Optimally, the focus is to achieve the shortest lead time (e.g. 1 day) with a one-stop visit, against the lowest costs.
- (ii) When all resources are organized in an autonomous work cell, risk of interference from other processes is minimized [12, 14]. Optimally, all activities are conducted in one autonomous work cell with three 'workstations' that are arranged in the processing sequence to facilitate flow: a cataract outpatient clinic, a cataract pre-assessment clinic and a cataract surgery clinic.
- (iii) In a lean pathway, the physical layout of resources aligns all activities in the processing sequence of the cataract pathway to prevent delays, caused by crossing the physical boundaries of autonomous workstations [12, 14, 28]. Optimally, patients need only two transfers to access and to leave the autonomous work cell.
- (iv) In a lean pathway, team members are multi-skilled [12, 14]. A lean care team combines maximum flexibility to conduct tasks interchangeably, as far as competence allows, with a minimal transfer of information and responsibilities [28]. A cataract team of ophthalmologists, anaesthetists and nurses, has all required competencies to do this.
- (v) Pull planning is used to directly couple resources to activities on demand [8, 14]. Separate coordination between activities can lead to waiting of patients or staff. Optimally, the patient's referral acts as a customer order decoupling point, after which all activities are directly scheduled and executed.

- (vi) In a lean pathway, all non-value added wastes are eliminated [8, 12, 14]. As routine medical testing for patients having local anaesthesia have not been found to reduce the incidence of intra- or post-operative complications [29], additional assessments (e.g. electrocardiogram (ECG), blood tests and internist consultations) can be considered as overprocessing. The patient's visit to the hospital for a first review by an ophthalmologist can also be considered as overprocessing, as this review is no longer recommended [24]. Self-reviews by patients, with a telephone call to a trained nurse when necessary, provide a safe alternative to reviews performed by ophthalmologists [30]. Coordination actions can also be a form of overprocessing. Optimally, six actions are needed to coordinate the patient's pathway (e.g. information transfer from referrer to ophthalmologist; from ophthalmologist to nurse; from nurse to anaesthetist; from anaesthetist to surgical care team; from surgical care team to nurse for first review; from nurse to back office to confirm discharge).

**Box 1** Eight activities (in italics) in a standard cataract pathway

**Diagnosis**

Cataract patients are referred to an ophthalmologist by their general practitioner or an optometrist, usually with symptoms of gradual blurring of vision. The ophthalmologist performs an ophthalmic examination to confirm the *diagnosis* of visually significant cataract and discusses the refractive aim of the surgery with the patient.

**Pre-assessments**

A *surgery* slot is *scheduled* together with the patient.

Ultrasound *biometry* is conducted to predict the correct lens implant power.

The nurse conducts a *nursing anamnesis* to assess if the patient is able to cooperate with the surgical procedure.

An anaesthetist conducts a preoperative *anaesthetic screening* to evaluate the risk associated with anaesthesia and surgery.

Additional assessments are performed, when required by the patients' general health (e.g. electrocardiogram (ECG), blood tests and an internist consultation).

**Cataract surgery**

Preoperatively, the ophthalmologist *formulates a surgical care plan* including details on type and power of the implant lens, based upon the discussed refractive aim of the surgery and the ultrasound biometry.

The current standard of *cataract surgery* in the developed world is phacoemulsification with intraocular lens implantation, which is typically performed under local anaesthesia as a same-day, outpatient procedure.

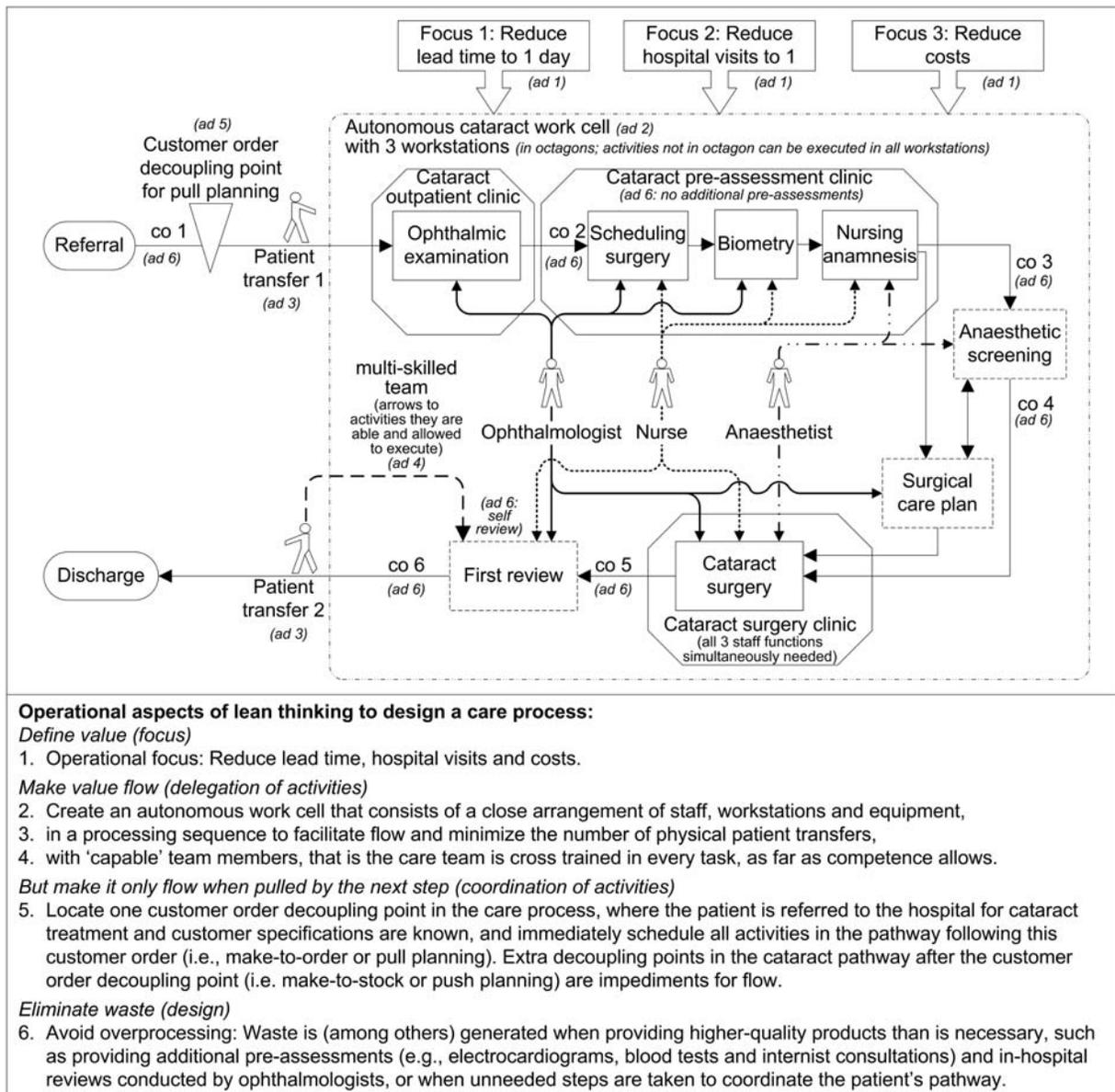
**First review**

Between 2 and 30 h after surgery, a *first review* is conducted to identify any early postoperative complications.

**Measures of lean aspects**

To analyse to what extent actual patient routes in the cataract pathways matched the lean framework, we constructed flow charts of the cataract pathways, based upon data on patient volumes per activity.

- (i) We determined if the cataract team focused on (a) reducing lead times, hospital visits and/or costs. To better understand operational focus, we also took into account (b) the environmental context.
- (ii) We determined (a) how many workstations were involved in delivering cataract care, which workstations were included in an autonomous cataract work cell and which were arranged in the processing sequence to facilitate flow. We analysed how many patients received their (b) diagnosis, (c) pre-assessments, (d) surgery and (e) first review in workstations that were part of an autonomous cataract work cell.
- (iii) To determine if workstations were aligned in the processing sequence, we analysed, based upon the actual patient routes and the identified number of workstations and locations, the average number of physical patient transfers.
- (iv) To determine if a multi-skilled team was installed, we analysed (a) the number of different staff functions in the cataract team and what staff functions (b) scheduled the surgery, conducted the (c) biometry, (d) nursing anamnesis and (e) first review. Other activities required specific competencies and could not be conducted by different staff functions.
- (v) To determine the use of pull planning, we analysed how many patients received (a) one-stop diagnosis (e.g. no separate visit for formulating a surgical care plan), (b) one-stop pre-assessments (e.g. pre-assessments finished at the same day as the diagnosis) and (c) one-stop surgery (e.g. surgery conducted at the same day as the diagnosis). We also analysed (d) how many patients received their admission date for surgery directly after their diagnosis. Furthermore, we determined (e) the number of decoupling points in the cataract pathway (e.g. a succeeding activity is decoupled with a previous activity and needed separate scheduling effort).
- (vi) To measure to what extent non-value added wastes were eliminated, we analysed (a) the number of patients who did not receive any additional pre-assessments and (b) the number of patients who did not revisit the hospital for a first review by an ophthalmologist. Furthermore, we analysed (c) the number of average coordination actions per patient. Each activity that was executed by a different team member required coordination. In case the patient revisited the hospital, two additional coordination actions were needed, i.e. one for transferring the patient record and one for scheduling the appointment.



**Figure 1** Lean framework, showing six operational aspects of lean thinking to design a cataract pathway. Block with dotted line, patient not in hospital; Co, Coordination.

### Efficiency measures

To evaluate efficiency of the cataract pathway, we analysed average lead times, average number of hospital visits per patient and average direct costs. Lead time is split in access time to the hospital and waiting time for cataract surgery. Access time was defined as the number of days between contacting the hospital and the first consultation. Waiting time for surgery was defined as the number of days between the first consultation and the surgery.

We analysed the average number of hospital visits per patient and determined how many patients visited the hospital once and how many patients visited the hospital twice (e.g. one visit for diagnosis and pre-assessments, one visit for surgery).

To systematically compare direct costs of the different process designs, we only took into account personnel costs that were made to execute and coordinate the eight activities in the cataract pathway and devised a standard cost per team member, based upon the Dutch hourly wages in Euro's (€). Furthermore, we applied the ceteris paribus assumption for all other costs such as material costs and indirect costs. Direct costs were estimated using activity-based costing [31, 32]. We calculated for each activity in the cataract pathway the activity costs. Members of the cataract team were interviewed to identify the responsible team member(s) and the allocated time for executing each activity. To calculate the activity costs, we multiplied the standard cost of the responsible team member(s) with the allocated time. To determine the total

costs, we used the quantitative measurements and flow charts of the cataract pathways and established how many patients underwent each activity and multiplied this number with the corresponding activity costs. To determine the average direct costs per patient, we divided the total costs by the number of included patients. We represented the direct costs per patient as an index number. The direct costs per patient in the lean framework equalled an index value of 100.

## Data collection

A staff member of the planning department from each hospital collected quantitative data on patient volumes per activity in the cataract pathway, lead times and number of hospital visits per patient from the hospitals' databases, conform a protocol, specifying details on definition and measurement of all variables. One of the researchers (L.M.K.) verified whether the data were collected conform protocol.

The same researcher (L.M.K.) visited each hospital for a 2-week period to observe the cataract team and to identify the physical layout of different workstations and locations involved in delivering cataract care and the processing sequence of activities.

The researcher (L.M.K.) conducted semi-structured interviews with two nurse managers, one manager of the planning department, three cataract surgeons, three nurses and two administrative staff members. The questions covered organization of work in the cataract pathway, the operational focus, environmental context, physical layout of the cataract pathway, allocation of resources, cross training and reasons for not using lean aspects. Directly after the interview, an interview report was written, describing the cataract pathway. One day after the interview, a second meeting was arranged to validate the process description and obtain approval on the interview report. After the case visit was finished, the process description was sent by email to the responsible nurse manager to validate the final content.

## Results

### Design of the cataract pathways

The operational focus in the cataract pathways was distinctively influenced by external circumstances (Table 1), leading to different orientations on efficiency (Table 2). Hospital 1 focused on reducing the number of visits and realized an average number of three visits per patient (Table 2). To reduce the number of visits, this hospital implemented one-stop diagnosis for all patients ( $n = 9195$ , 100%) and one-stop pre-assessments for nearly half of their patients ( $n = 4376$ , 48%; Fig. 2). Hospital 1 trained nurses to conduct biometry, schedule the surgery and conduct a same-day review after surgery (Box 2). The 109 days lead time just matched the National Health Service '18-week pathway' objective that stated that nobody should wait longer than 18 weeks after referral to hospital treatment. Nurse managers mentioned that waiting time for surgery slightly decreased the past years due to efforts to

achieve this objective, but they did not experience strong incentives to further reduce waiting time.

Hospital 2 operated in a competitive environment with a fee-for-service system (Table 1). They focused on direct access and realized an average lead time of 15 days (Table 2). To minimize time to surgery, ophthalmologists did not reserve any of their outpatient slot capacity for specific patient groups and operated most patients ( $n = 7366$ , 84%) in a high-volume cataract surgery clinic (Fig. 2). Ophthalmologists told us that they were aware of redundant procedures in the cataract pathway (Box 2). These were mainly prompted by fear of malpractice claims.

Hospital 3 was facing a shortage of ophthalmologists and nurses in a cost-competitive environment (Table 1) and focused on decreasing costs (140% of minimum costs) (Table 2). This hospital selected for each activity the lowest skilled employee (Fig. 2). Nurse managers mentioned that coordinating care was difficult, as each activity was conducted in another workstation, with different opening hours and an independent capacity planning. A cataract surgeon mentioned that regularly, when general ophthalmologists or residents admitted patients for cataract surgery, the refractive aim of the surgery was not registered. Patients then revisited the cataract surgeon to formulate a surgical care plan (Box 2).

### Comparison of lean aspects in the cataract pathways

None of the hospitals created one autonomous work cell in which all workstations were arranged in the processing sequence to facilitate flow between succeeding activities (Table 1). Nurse managers in all three hospitals mentioned that most patients were referred without a preliminary diagnosis for cataract and that only ophthalmologists and properly trained optometrists can accurately diagnose cataract and predict the need for cataract surgery. Therefore, to cope with the uncertain arrival pattern of cataract patients, all hospitals employed a general outpatient clinic with a shared pre-assessment clinic and used frequent batching to schedule cataract surgery, without organizing one-stop surgery (Table 1). Nurse managers in Hospital 1 and 3 mentioned that they experienced that elderly cataract patients appreciated a little time between the decision for surgery and the surgery itself, so they could arrange their personal lives for the surgery and the first postoperative days.

Compared with Hospital 1 and 3, patients in Hospital 2 needed on average more physical transfers, mainly to finish their pre-assessments and to visit the ophthalmologist 1 day after surgery (Table 1), but this was not associated with a longer lead time (Table 2).

Although in Hospital 3 two team members could schedule the surgery and three members, including the patient, could conduct the first review (Table 1), this cross training was not used to build-in flexibility, but to free-up time of ophthalmologists and nurses. In Hospital 1 and Hospital 2, multi-skilling of, respectively, nurses and ophthalmologists were used to integrate activities in one-stop procedures and to reduce the need for coordination. Compared with Hospital 1 and 2,

**Table 1** Scores on six operational aspects of lean thinking in the cataract pathways of three eye hospitals for first eye cataract surgery in 2006

	Lean framework	Hospital 1 ( <i>n</i> = 9195)	Hospital 2 ( <i>n</i> = 8761)	Hospital 3 ( <i>n</i> = 4093)
<b>1. Operational focus</b>				
(a) Focuses	Reduce lead time + hospital visits + costs	Reduce hospital visits	Reduce lead time	Reduce costs
(b) Environmental context	NA	Difficult accessible location; 18 week pathway	Fee-for-service	Shortage of ophthalmologists and nurses
<b>2. Autonomous work cell</b>				
(a) Number of workstations*	3	6	8	9
In <i>Italic</i> : workstations included in an autonomous cataract work cell. Others: autonomous workstations. Workstations between square brackets: arranged in processing sequence.	[ <i>cataract outpatient clinic, cataract pre-assessment clinic, cataract surgery clinic</i> ]	[general outpatient clinic, <i>cataract outpatient clinic</i> , pre-assessment clinic], [general OR, ward], <i>cataract surgery clinic</i>	general outpatient clinic, private clinic, private primary care centre, pre-admission testing area, internist, general OR, ward, <i>cataract surgery clinic</i>	[general outpatient clinic, <i>cataract outpatient clinic</i> , pre-assessment clinic], laboratory, internist, biometry dept., [general OR, ward], <i>cataract surgery clinic</i>
(b) Diagnosis in autonomous work cell	100%	8160 (89%)	0 (0%)	580 (14%)
(c) Pre-assessments in autonomous work cell	100%	0 (0%)	0 (0%)	0 (0%)
(d) Surgery in autonomous work cell	100%	6309 (69%)	7366 (84%)	2630 (64%)
(e) First review in autonomous work cell	100%	6309 (69%)	0 (0%)	2497 (61%)
<b>3. Lean physical lay-out</b>				
Physical patient transfers per treatment	2.0	8.3	11.1	9.2
<b>4. Multi-skilled team</b>				
(a) Number of different staff functions	3	5	6	8
(b) Staff scheduling surgery	Nurse, ophthalmologist	Nurse	Ophthalmologist	Planning coordinator, nurse
(c) Staff conducting biometry	Nurse, ophthalmologist	Nurse	Ophthalmologist	Ophthalmic assistant
(d) Staff conducting nursing anamnesis	Nurse, anaesthetist	Nurse	Nurse	Nurse
(e) Staff conducting first review	Patient, nurse, ophthalmologist	Nurse	Ophthalmologist	Nurse, ophthalmologist, patient
<b>5. Pull planning</b>				
(a) One-stop diagnosis	100%	9195 (100%)	8761 (100%)	1373 (34%)
(b) One-stop pre-assessments	100%	4376 (48%)	2523 (29%)	1794 (44%)

Continued

Table 1 Continued

	Lean framework	Hospital 1 ( <i>n</i> = 9195)	Hospital 2 ( <i>n</i> = 8761)	Hospital 3 ( <i>n</i> = 4093)
(c) One-stop surgery	100%	0 (0%)	0 (0%)	0 (0%)
(d) Direct scheduling of surgery	100%	8160 (89%)	8761 (100%)	1846 (45%)
(e) Number of decoupling points	1	10	9	14
6. Elimination of wastes				
(a) No additional assessments	100%	1839 (20%)	0 (0%)	1584 (39%)
(b) No in-hospital ophthalmologist review	100%	9195 (100%)	0 (0%)	2906 (71%)
(c) Coordination actions per patient	6	8.5	13.8	16.3

The scores in the lean framework column represent the ideal outcomes as achieved in Fig. 1.

\*In *Italic*: workstations included in an autonomous cataract work cell. Others: autonomous workstations. Workstations between square brackets: arranged in the processing sequence.

Table 2 Efficiency outcomes in the cataract pathways of three eye hospitals for first eye cataract surgery in 2006.

	Lean framework	Hospital 1 ( <i>n</i> = 9195)	Hospital 2 ( <i>n</i> = 8761)	Hospital 3 ( <i>n</i> = 4093)
Lead time in days	1	109.2	15.0	91.0
Access time	0	31.5	0.0	25.0
Waiting time for surgery	0	77.7	15.0	66.0
Number of hospital visits per patient	1.0	3.0	3.6	3.2
Patients with 1 hospital visit	100%	0 (0%)	0 (0%)	0 (0%)
Patients with 2 hospital visits	0%	4376 (48%)	0 (0%)	1274 (31%)
Index number direct costs per patient <sup>a</sup>	100.0	128.6	153.0	139.7

The outcomes in the lean framework column represent the ideal scores as achieved in Fig. 1.

<sup>a</sup>The direct costs per patient in the lean framework equalled an index value of 100.

Hospital 3 created more decoupling points and needed on average more than 16 actions to coordinate the patient's care through the highest number of workstations that employed the highest number of different staff functions (Table 1).

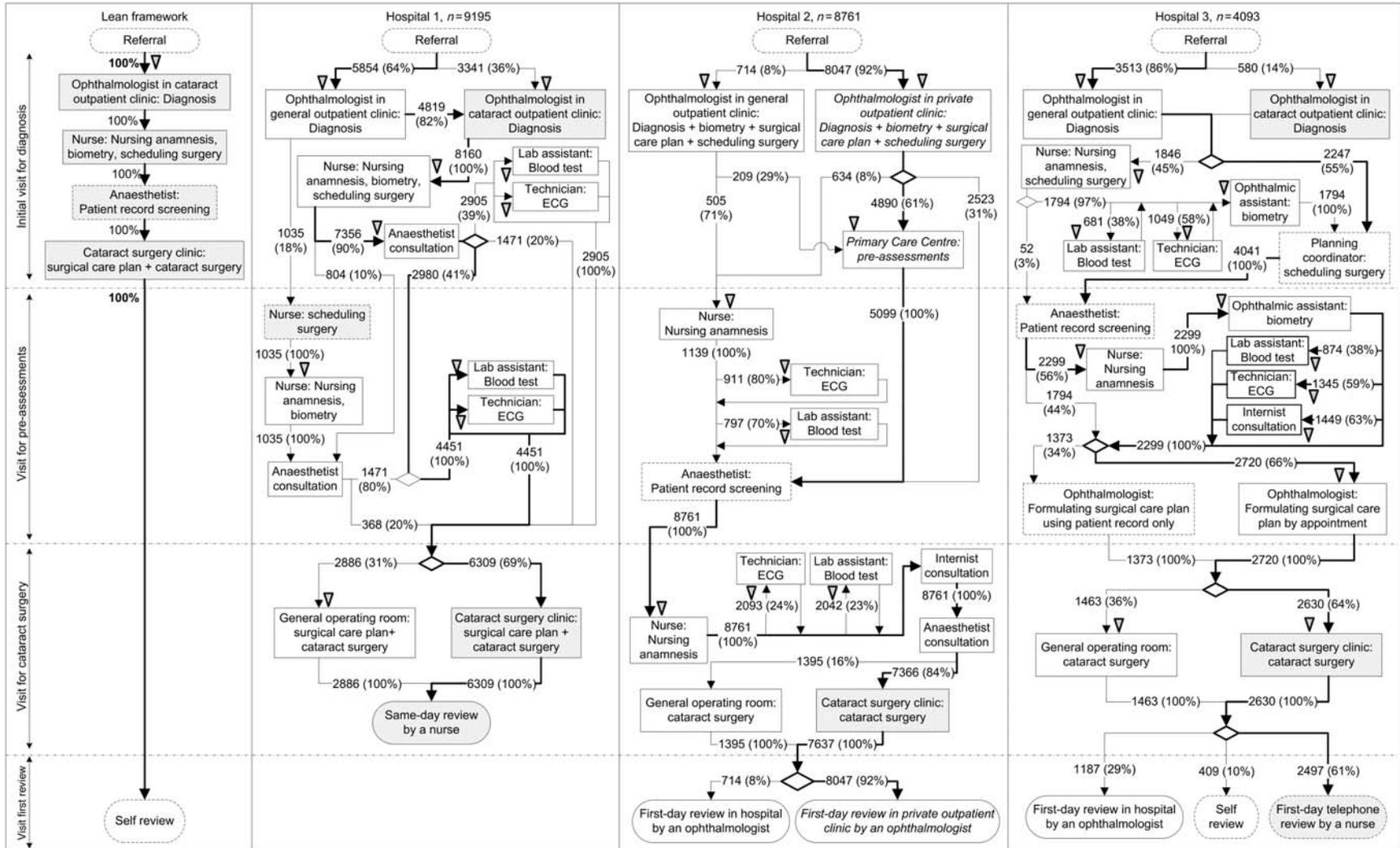
## Discussion

The environmental context and operational focus primarily determined how other lean aspects were applied to design the cataract pathway. Because none of the healthcare systems provided aligned incentives to reduce lead times, hospital visits and costs at the same time, hospitals behaved differently in organizing their cataract pathways in order to meet their external expectations and metrics [33]. In this study, lean aspects seemed to be associated with higher efficiency. Pull planning with integrating activities in one-stop procedures conducted by multi-skilled nurses, as well as eliminating wastes, reduced both the number of hospital visits and costs. Short lead times were associated with the use of a

general outpatient clinic in combination with a high-volume cataract surgery clinic.

The majority of cataract patients were diagnosed and admitted for surgery at general consulting hours. We argue that the initial ophthalmic examination rather than the referral acts as the customer order decoupling point in the cataract pathway. This pleads for creating two autonomous work cells, one for diagnosis, enclosing the general outpatient clinic to 'process' all different kinds of ophthalmic patients, and one for high-volume cataract care. After the diagnosis for cataract, all succeeding activities are predictable and can be organized in a continuous flow at a rate determined by the customer's demand in the cataract autonomous work cell.

Kujala *et al.* [27] and Peltokorpi and Kujala [34] divide waiting times in a patient episode in positive, passive and negative waiting times. As cataract cannot improve spontaneously but gradually worsens, it is likely that there is mainly negative waiting time. This might support our hypothesis that the optimal lead time in a lean cataract pathway is 1 day. However, in this study, we did not explore how much



**Figure 2** Flow charts of the cataract pathways in the three eye hospitals for first eye cataract surgery in 2006. The flow chart of the lean framework represents the ideal patient journey, as shown in Fig. 1. Block: team member executing one or more activities in a workstation. Block with dotted line: patient not in hospital. Block with striped pattern: workstation that is part of an autonomous cataract work cell. Italic text: activities that are executed outside the hospital organization. Fat line: main patient route in the cataract pathway. Inverted triangle: decoupling point in the cataract pathway.

time between different processing steps is valued by patients. As a delay up to 6 weeks does not influence the prognosis of the success of the surgery [35], patients can safely be offered a little passive waiting time. Further research on preferred waiting times among patients can be useful for this purpose.

None of the hospitals provided one-stop surgery. They were risk-averse for having under-utilization of expensive operating room resources for an elective surgical procedure. When there is a shortfall of patients admitted for surgery on the day, operating room capacity is wasted [36]. As the added value of one-stop surgery for both the patient and the hospital remained unclear, we argue that frequent batching is a more appropriate technique to schedule cataract surgery than pull planning.

### Box 2 Organization of the cataract pathways in the three eye hospitals for first eye cataract surgery in 2006

#### Hospital 1, $n = 9195$

When patients were referred to Hospital 1, the referrer sent a referral letter to the booking centre. A member of the booking centre booked patients who were under suspicion of suffering from cataract on a cataract consulting hour ( $n = 3341$ , 36%). Because the hospital was located in a difficult accessible city centre, patients had long travel times. Patients that were diagnosed with cataract in the general outpatient clinic ( $n = 5854$ , 64%) were directly [and if capacity was available ( $n = 4819$ , 52%)] referred to the cataract outpatient clinic.

Following the outpatient consultation in the cataract clinic, a nurse in the pre-assessment clinic conducted the nursing anamnesis and biometry and booked an admission date for surgery ( $n = 8160$ , 89%). Patients were seen by an anaesthetist (if available) and received additional pre-assessments if required by the patient's health and if capacity was available. In case pre-assessments were not finished, patients ( $n = 4819$ , 52%) received a separate appointment.

Most patients were operated in a cataract surgery clinic ( $n = 6309$ , 69%). Patients that underwent surgery under general anaesthetics or that suffered from severe (ocular) comorbidities were operated in the general operating room ( $n = 2886$ , 31%).

Two hours after surgery, a nurse inspected the operated eye for any early postoperative complications, after which the patient was discharged ( $n = 9195$ , 100%).

#### Hospital 2, $n = 8761$

Most cataract patients ( $n = 8047$ , 92%) received their diagnosis outside the hospital in a private outpatient clinic. After the diagnosis, ophthalmologists conducted the biometry, formulated the surgical care plan and booked the admission date for surgery ( $n = 8761$ , 100%).

Most patients ( $n = 5099$ , 58%) visited a Primary Care Centre outside the hospital to receive their nursing

#### Box 2 Continued

anamnesis, an internist consultation (for their medical clearance) and additional pre-assessments if required. The hospital offered private patients ( $n = 2523$ , 29%) the possibility of same-day testing. The other 1139 patients (13%) preoperatively visited the pre-admission area in the hospital to receive their pre-assessments. Forty-eight hours before surgery, the anaesthetist screened the patient record to assess the anaesthetic risk. At the day of surgery all patients ( $n = 8761$ , 100%) received an extra nursing anamnesis by a nurse. To avoid potential liability, all patients received an internist consultation and were seen by an anaesthetist. Most patients ( $n = 7366$ , 84%) were operated in a cataract surgery clinic. Patients that underwent surgery under general anaesthetics or that suffered from severe (ocular) comorbidities were operated in the general operating room ( $n = 1395$ , 16%).

The day after surgery, the ophthalmologist inspected the operated eye for any early postoperative complications in the private outpatient clinic ( $n = 8047$ , 92%) or the outpatient clinic inside the hospital ( $n = 714$ , 8%).

#### Hospital 3, $n = 4093$

Most cataract patients ( $n = 3513$ , 86%) received their diagnosis in the general outpatient clinic.

Hospital 3 organized walk-in sessions in their pre-assessment clinic, to give patients a nursing anamnesis, an admission date for surgery and additional pre-assessments the same day ( $n = 1794$ , 44%). An ophthalmic assistant conducted the biometry in a different department outside the pre-assessment clinic. When walk-in capacity of the pre-assessment clinic was already fully booked, patients ( $n = 2299$ , 56%) received a separate appointment. The hospital started to integrate formulating the surgical care plan in the initial consultation, so they could offer patients a one-stop diagnosis ( $n = 1373$ , 34%). Cataract surgeons discussed the refractive aim of the surgery with the 2720 other patients (66%) in a separate appointment.

Most patients ( $n = 2630$ , 64%) were operated in a cataract surgery clinic. Patients that underwent surgery under general anaesthetics or that suffered from severe (ocular) comorbidities were operated in the general operating room ( $n = 1463$ , 36%).

The day after surgery, either a nurse conducted a telephone review, enabling patients ( $n = 2497$ , 61%) to stay at home, or the ophthalmologist inspected the operated eye for any early postoperative complications in the hospital ( $n = 1187$ , 29%). Another 409 patients (10%) were instructed to call the hospital in case they had a red eye or pain (e.g. self-review).

In accordance with Lansingh *et al.* [37] the cataract pathways in the UK and the Netherlands were more cost-effective than the cataract pathway in the USA. The

fee-for-service system in the USA seems to encourage physicians to treat more patients [38] and to execute redundant activities, such as internist consultations for all patients. Furthermore, this study shows that a more integrated pathway as in Hospital 1 (UK), with less need for coordination, resulted in lower direct costs compared with a fragmented pathway as in Hospital 3 (NL).

A restriction of the study is the limited number of cases. To increase understanding of the relation between process design and efficiency in different environmental contexts, we recommend conducting a larger multi-centre longitudinal benchmark study. The methodology described in this study could be feasible to use in such a large study. Added value of this study is the specification of six operational aspects of lean thinking in a framework to systematically compare process designs. Further research to applications of lean thinking in healthcare could help to expand the characteristics that should be found in lean pathways. We recommend developing a method to calculate to what extent hospitals implemented lean thinking, as this would enable a quantitative analysis of the impact of lean thinking on outcome measures. The association of value with an operational, clinical and experiential dimension, as described by Young and McClean [39], may help to evolve the framework developed in this study.

In respect to operational value, we suggest that further research should include operational aspects for work design and production control. For example, lean thinking encloses instruments for mistake-proofing that could increase safety of care, instruments for production levelling that could be used to integrally manage patient flows and resources, or instruments for analysing takt times that could be used to identify which parts of a process are creating delays.

As clinical and patient-related outcome measures primarily determine value for the customer, we recommend further research to the relation between process designs of more complex surgical pathways and these outcome measures. We excluded clinical outcomes in this study because most patients experience a significant increase in vision outcome after cataract surgery [4], incidence of complications is low [24, 25] and complications that may result in permanent vision loss are rare [40].

Joosten *et al.* [41] reported that the sociotechnical influence of lean thinking on staff has been explicitly criticized. Most organizations applied lean thinking to increase productivity and quality with experiential value as pleasant by-product [41, 42]. However, implementing lean thinking also includes learning how to feel comfortable working in cross-functional teams, to share knowledge and create mutual respect [13]. Gittell *et al.* [43] reported that the relational coordination between member in such teams positively affect the quality of care. To better understand the impact of lean thinking on both staff and patient experience, we recommend further research to the relation between applying lean thinking, team performance and experiential values.

In conclusion, operational focus seemed to have a stronger influence on process design and resulting efficiency than other lean thinking principles. When pressed to further

optimize their processes, hospitals can use these systematic benchmarking data to decrease the frequency of lead times, hospital visits and costs.

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