Complexity complicates lean: Lessons from seven emergency services

ARTICLE in JOURNAL OF HEALTH ORGANISATION AND MANAGEMENT · MAY 2014
Impact Factor: 0.36 · DOI: 10.1108/JHOM-03-2013-0060
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Complexity complicates lean: lessons from seven emergency services

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Abstract

Purpose – The purpose of this paper is to explain how different emergency services adopt and adapt the same hospital-wide lean-inspired intervention and how this is reflected in hospital process performance data.

Design/methodology/approach – A multiple case study based on a realistic evaluation approach to identify mechanisms for how lean impacts process performance and services’ capability to learn and continually improve. Four years of process performance data were collected from seven emergency services at a Swedish University Hospital: ear, nose and throat (ENT) (two), pediatrics (two), gynecology, internal medicine, and surgery. Performance patterns were linked with qualitative data collected through realist interviews.

Findings – The complexity of the care process influenced how improvement in access to care was achieved. For less complex care processes (ENT and gynecology), large and sustained improvement was mainly the result of a better match between capacity and demand. For medicine, surgery, and pediatrics, which exhibit greater care process complexity, sustainable, or continual improvement were constrained because the changes implemented were insufficient in addressing the higher degree of complexity.

Originality/value – The variation in process performance and sustainability of results indicate that lean efforts should be carefully adapted to the complexity of the care process and to the educational commitment of healthcare organizations. Ultimately, the ability to adapt lean to a particular context of application depends on the development of routines that effectively support learning from daily practices.

Keywords Complexity, Learning, Lean, Emergency care, Realistic evaluation, Waiting time

Paper type Research paper
Introduction
Since early 2000, lean has become the approach to healthcare improvement most commonly reported in the literature (Walshe, 2009; Brandao de Souza, 2009). Both Great Britain’s National Health Service (NHS) and the Joint Commission Institute in the USA have promoted the use of lean thinking as a strategy to help healthcare organizations provide more value to their patients, while at the same time using less resources (Jones and Mitchell, 2006; Zak, 2006). In Sweden, nine out of ten hospitals claim to have implemented lean to some extent (Weimarsson, 2011). However, whether and how the benefits of lean thinking seen in manufacturing can be emulated in healthcare remains uncertain (Brandao de Souza and Pidd, 2011; Radnor et al., 2012).

In manufacturing, lean thinking has been characterized by the development of three capabilities: process, learning, and evolutionary (Fujimoto, 1999). Process capability involves routines which reduce non-value adding activities and process variation in order to increase customer value (Modig and Åhlström, 2012; Radnor et al., 2012; Fujimoto, 1999). Learning capability involves routines for problem identification, problem solving, and solution retention (Jones et al., 1997; Fujimoto, 1999). Evolutionary learning capability involves an organization’s ability to generate new and better ways of working – to innovate.

Lean healthcare
In a recent realist literature review, we examined how lean has been applied in healthcare and what about lean works, for whom, and why (Mazzocato et al., 2010). We found no indications of an evolutionary learning capability but evidence of both process and learning capabilities.

Process capability. The majority of lean applications focus on strengthening process capability, often in emergency departments (ED) (Holden, 2011; Mazzocato et al., 2010). This typically begins by defining value from the patient perspective, such as the timeliness of care. All the steps that add value to the patient are linked seamlessly together in a value stream (Jones and Mitchell, 2006; Zak, 2006). In order to achieve a smooth flow of operations, multiple changes to the workflow and the physical layout are often implemented in combination (Mazzocato et al., 2010). A common change in EDs is the use of “process streaming” through the development of care processes designed around patient groups that utilize similar constellations of resources (Walley, 2003). Streaming has been based on the likelihood that patients will be admitted or discharged (King et al., 2006; Kelly et al., 2007), and on their need for further diagnostics or care (Walley, 2003). In EDs, the most commonly reported results are reduced waiting times and length of stay (King et al., 2006; Kelly et al., 2007; Ben-Tovim et al., 2008).

To summarize the literature on lean applications regarding process capability, lean is a strategy for how to plan, design, and manage operations to achieve continuous patient flow and thereby improve operational performance (e.g. reduce lead and waiting times).

In our previous review, we found that the majority of studies concerned single cases of lean applications and noted the inherent limitations this entails when seeking to understand how and why lean applications work in interaction with different contexts (Mazzocato et al., 2010). In other words, it is difficult to know if variation in performance is due to the content of the lean changes, to the context of their application, to the process of implementation, or to interactions between the three (Pettigrew and Whipp, 1993). Comparative multiple-case studies of lean applications could help clarify this knowledge gap (Walshe, 2007).
Concerning learning capability, lean applications in healthcare typically focus on three types of methods (Mazzocato et al., 2010): methods to understand processes in order to identify and analyze problems (e.g. value stream mapping); methods to improve error detection, to relay information to problem solvers, and to prevent errors from causing harm (e.g. a patient safety alert system); and methods to manage change and solve problems with a scientific approach (e.g. multidisciplinary improvement teams).

The use of these methods make processes more explicit and standardized and help staff recognize how work is currently, and should ideally, be carried out. This makes deviations from standardized procedures easier to detect and manage. Stable and systematic approaches to problem solving, including management involvement, can then help staff continually learn and improve (Mazzocato et al., 2010).

Given the evident focus health care organizations have on tools and the short-time frame of most studies, it is unclear how organizations have invested in the development of a learning capability to achieve continual improvement (Mazzocato et al., 2010).

Aim
In summary, there are gaps in our ability to explain how lean applications can yield varied results and how health care organizations develop the capability for continual improvement. We therefore undertook a comparative study of how different emergency services adopted and adapted the same hospital-wide lean-inspired intervention and how this was reflected in performance over time to illuminate the development of process and learning capabilities.

Methods
Study setting
Karolinska University Hospital is a publicly owned and funded tertiary academic medical center which, after a merger in 2004, operates at two main sites. The hospital primarily serves a population of two million inhabitants within the Stockholm County, Sweden. In 2012, it had 15,500 employees (including salaried doctors), 1,736 beds, 200,000 patient visits/year in its three EDs, and an annual operating budget of SEK14.2 billion ($2.0 billion).

The lean program. In 2007, hospital management initiated a strategic hospital-wide and long-term lean-inspired program to improve care processes, particularly the timeliness of care and the working environment. The implementation process was designed and facilitated by the hospital’s strategic services development unit. The effort began with the 16 emergency services which together generated over 60 percent of all hospital admissions. Initially limited to week-day business hours, the hospital’s strategy was guided by three specific goals, which were developed by taking into account the current performance and the estimated level of improvement needed to achieve a smooth patient flow at the EDs:

1. reduce average time between patient arrival and initial physician assessment to 40 minutes;
2. increase the throughput of patients at the ED so that 90 percent can leave within four hours; and
3. reduce the number of patients present at the ED at the 4 p.m. shift change.

All ED services were guided by one of three coaches from the hospital’s strategic services development unit. Multidisciplinary process improvement teams were created
at each ED service and were typically composed of one to two representatives from different professions including registered nurse (RNs) and licensed practical nurse (LPNs) with one physician (often a specialist or senior resident) appointed as a process leader. Starting in autumn 2007, the improvement teams began to map their service's care process to identify non-value adding time from the patient perspective. Each team developed a “process prototype” which they iteratively tested and developed. The coaches advised teams to address five key intervention areas in their process prototypes (Table I): how work was organized; which competence level should be present at the ED and how work should be organized taking into account different competence levels; how to free staff from multiple and competing tasks; how to adapt staffing levels to typical demand patterns; and how to ensure continual improvement. The coaches also suggested key changes within each intervention area.

<table>
<thead>
<tr>
<th>Key intervention areas</th>
<th>Suggested key changes</th>
<th>Implementers’ ideas of how the changes were expected to improve performance</th>
</tr>
</thead>
</table>
| Way of working                          | Introduce teamwork and changes to physical layout  
Introduce flow managers (a flow physician and a flow nurse)                                                                                               | Facilitate work done in parallel and care giver coordination  
Coordinate patient flow and workflow by assigning patients to care teams                                                                                                          |
| Competence                              | Utilize the most competent physician (the flow physician) as early as possible in the process                                                                                                                        | Get assessment and case management right from the start by supporting and supervising a heterogeneous group of junior and rotating physicians in the initial phases of the diagnostic and treatment processes, e.g. by partaking in the initial physician assessment  
Reduce avoidable workflow interruptions                                                                                                                   |
| Free staff from multiple and parallel tasks | Move competing tasks such as telephone consultations or required educational activities out of the ED  
Change staffing levels and schedules                                                                                                                           | Match staffing to typical demand patterns  
Enable learning and continual improvement                                                                                                           |
| Staffing                                | Introduce visual management systems including a takt board\(^a\) and a whiteboard\(^b\) to identify and document daily flow problems  
Bimonthly process improvement meetings between the process team and a coach  
Monthly meetings between process leaders and the hospital management team (the hospital CEO, directors of the different divisions and the strategic services development unit, and pertinent department chiefs and first-line managers) | Analyze current performance and develop solutions for continual improvement  
Based on suggestions from the floor  
Help senior managers identify, select, and support improvement suggestions from the process team                                                                 |

Notes: \(^a\)The takt board is a computer-based tool to monitor the number of patients assessed by physicians per hour. This is compared to the expected pace calculated based on the average hourly patient inflow rate for that hour plus one standard deviation. In the event of deviations from the expected work pace, a link appears on the screen to enable flow managers to register possible causes to inform the subsequent design of countermeasures; \(^b\)the whiteboard is used to register process problems and propose possible solutions

Table I. The lean-inspired program
Study design
We used a multiple case study design (Yin, 1999, 2009) to compare how the lean program worked in different contexts of application. Seven of the 16 services were selected for analysis. Three were recommended by the strategic services development unit because they demonstrated either high (surgery and pediatrics (Peds-2)) or low adherence (Peds-1) to the changes they had suggested. Three were selected by the researchers because they had the best performance levels (both ear, nose, and throat (ENT-1 and ENT-2) and gynecology). Internal medicine (Medicine) actively sought to be included in the study, expressing criticism of and frustration with the lean intervention. The study was approved by the Regional Ethical Review Board.

We employed an approach grounded in realistic evaluation (Walshe, 2007; Pawson and Tilley, 1997). The underlying assumption of realistic evaluation is that complex social interventions are based on hypotheses and assumptions that can be stated explicitly, tested, and evaluated. The general logic model for a realistic evaluation is that an intervention (I) in a context (C) triggers a mechanism (M) which generates an outcome (O) (CMIO configurations) (Denyer et al., 2008; Pawson and Tilley, 1997). Mechanisms can thus explain how the same intervention can lead to different outcomes in different contexts of application (Walshe, 2007; Pawson and Tilley, 1997). In line with the realistic evaluation research cycle (Pawson and Tilley, 1997) we conducted the study in four phases: theory, hypothesis generation, observations, and program specification.

Phase 1: theory. Based on our review of the literature, we developed two preliminary program theories about how lean contributes to the development of process and learning capabilities (italicized in the introduction) (Mazzocato et al., 2010). Such program theories make explicit “the underlying assumptions about how an intervention is meant to work and what impacts it is expected to have” (Pawson et al., 2005, p. 21).

Phase 2: hypothesis generation. We developed a list of 21 plausible candidate mechanisms for process capability (11) and learning capability (ten) in EDs (see Appendix). Since our literature review yielded no evidence about the sources of variation in lean applications, we developed preliminary mechanisms instead of full CMIO configurations. These mechanisms were formulated to be context specific, informed by the hospital’s approach and our previous study of the lean-inspired program at the hospital in question (Mazzocato et al., 2011).

We articulated process capability mechanisms as hypotheses for how lean could influence the way individuals carry out their daily operations (mechanism 1), how they interact with one another (mechanisms 2-6), how staffing and competence are organized (mechanisms 7-10), and how care is coordinated across organizational boundaries (mechanism 11). We articulated learning capability mechanisms as hypotheses for how lean could influence the way staff and managers work to identify and solve problems (mechanisms 12-18), and sustain subsequent changes and continually improve (mechanisms 19-21).

Phase 3: observation. We combined qualitative and quantitative data to empirically test our mechanisms and to develop CMIO configurations for each case.

Quantitative data collection and analysis. To understand the impact (O) of lean on process performance, we obtained performance data from the hospital (in electronic format): waiting time from triage to first physician assessment and percentage of patients discharged from the ED within four hours from triage. These were expressed as monthly averages for weekdays, 8 a.m.-4 p.m. (the same window the improvement efforts focused on) and were collected for the period 2007-2011. The third goal (number of patients at 4 p.m.) was deemed by many of the services to be less relevant
because it did not reflect patient demand patterns. As a result, we did not collect any data for this third goal.

We used descriptive statistics to compare performance levels before and after the lean changes (each service implemented their initial process changes between April and December 2008). To assess achievements across services we analyzed performance levels for 2011. Statistical process control charts (SPC) were used to identify whether and when statistically significant changes in performance occurred and if they were sustained. SPC supports the identification of statistically significant changes in process performance through a set of rules which determine whether a change depends on chance, i.e. common-cause variation, or is due to an influence not previously part of the process such as an improvement effort, i.e. special-cause variation (Benneyan et al., 2003; Montgomery, 2005; Thor et al., 2007). We used two rules to identify special-cause variation: nine consecutive points on the same side of the pre-lean baseline or any single data point outside the three standard deviation limit (Montgomery, 2005). I-charts were used for “waiting time to first physician assessment” and P-charts for “percentage of patients ready within four hours” (Montgomery, 2005).

To characterize the contexts (C) of the ED services we collected additional quantitative data were collected from the hospital electronic systems: percentage of patients referred to other services, patient volumes, and admission rates.

Qualitative data collection and analysis. We conducted four group interview sessions of three hours each with 14 staff members (ten women and four men) who had been or were currently involved in the different multidisciplinary improvement teams. Two sessions were attended by representatives from multiple services; two from single services. The participants included physicians, RNs, LPNs, and midwives. Verbal informed consent was obtained from all individuals.

We employed a realist approach to interviewing (Pawson and Tilley, 1997). This entails a teacher-learner function where researchers make stakeholders aware of the overall conceptual structure that is being investigated and a conceptual refinement process where the researcher and the stakeholder confirm or falsify and then refine the candidate mechanisms against the stakeholders’ experience and understanding.

Each session began with researchers presenting their understanding of the lean program (i.e. teacher-learner function). This formed the basis for semi-structured interviews about how lean was implemented in each service in which open-ended and probing questions were systematically asked about each of the five intervention areas described in Table I. These interviews were conducted in smaller groups by the authors (P.M., C.S., U.B., and J.T.) and digitally recorded. Informants were then asked to individually rate on a four-step scale (considerable, moderate, slight, not at all) how prominent they perceived each candidate mechanism to be in their service (Pawson and Tilley, 1997). We collected and analyzed the ratings during a coffee break in the session and identified areas of similarity and discrepancy within or across the services. We then presented the results and facilitated a group discussion to identify factors that could explain why different mechanisms were activated (i.e. conceptual refinement). This group discussion was also recorded.

The group interviews and the discussion were transcribed verbatim. We combined the transcriptions with the quantitative data to develop rich case descriptions which were then used to formulate service specific CIMO configurations.

To develop contextual descriptions (C), we employed a framework (Carayon, 2009) from the field of job and organizational design which describes five key dimensions related to how a work system, such as an ED, influences individuals and thereby leads
to various outcomes such as job satisfaction, and patient safety: organizational (e.g. opening hours, educational requirements), tools and technology (e.g. number of rooms, technology available), person (e.g. composition of the workforce, competence available), task/process (e.g. work organization), and environmental factors (e.g. norms, work climate). The descriptions were enriched with data about the percentage of patients referred to other services, patient volumes, and admission rates.

Intervention descriptions (I) were organized according to the five lean program intervention areas described in Table I. The focus was on identifying differences between services and deviations from the hospital’s lean intervention model.

The mechanisms (M) activated in each service were confirmed, rejected or refined based on the group interviews and discussions.

Phase 4: program specification. We compared the service specific CIMO configurations to identify and explain similarities and differences in improvement patterns. Informants reviewed drafts of the case descriptions to validate or modify the findings which formed the basis for the refined program theories presented in the results.

Results
In this section we first present an intervention description (I) for each service (C), outcomes (O), and the cross-case CIMO comparison.

Intervention descriptions
Characteristics of the process prototypes adopted and adapted by the seven services as well as changes made after initial implementation can be found in Table II.

1. Way of working. All services initially introduced care teams involving RN/LPN-physician pairs. Peds-1, medicine, and surgery centralized team members’ work stations to the same room. ENT-1, gynecology, Peds-2, and surgery moved equipment (e.g. a medication trolley or sutures) into the examination rooms.

The two pediatrics, medicine, surgery, and gynecology, introduced the flow physician role. Usually specialists or senior residents, flow physicians communicated with junior or rotating physicians in the care team either before or after the initial patient assessment. In medicine, surgery, and both pediatric services, flow physicians could also see “see-and-treat” patients (patients with less life-threatening conditions who could be seen, treated, and discharged by one physician). At an early stage of the lean intervention, gynecology abandoned the role of the flow physician in favor of an approach whereby staff could share responsibility for all patients at the ED. Only two services eliminated and standardized diagnostic process steps: gynecology eliminated repetitious history taking and triage as well as standardized tests that were taken prior to initial physician consultation; medicine standardized a deep vein thrombosis (DVT) patient care process. gynecology, medicine, and surgery implemented process changes that involved units outside the ED, e.g. medicine collaborated with the physiology lab to improve access to diagnostic services for patients with suspect DVT.

2. Competence. ENT-2 and gynecology increased the competence level of physicians involved in direct patient care (the care team physician). The two pediatrics and medicine increased physician competence by only scheduling specialists as flow physicians and medicine also added a resident to manage consultation from within the hospital. In these services the competency levels in the care teams remained varied; the physician role could include specialists, residents, rotating residents from associated specialties, interns, or medical students. Surgery made attempts to have a specialist as the flow physician, but experienced considerable difficulties in convincing specialists...
### Lean intervention areas

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<td><strong>Way of working</strong></td>
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<td>Introduce RN/LPN-MD pairs</td>
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<tr>
<td>Introduce flow nurse role</td>
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<td>Introduce flow physician role</td>
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<td>Move equipment into the patient room</td>
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<td>Eliminate and standardize diagnostic process steps</td>
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<td>Develop process changes involving units outside the ED</td>
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<td><strong>Competence</strong></td>
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<td>Increase competence level of physicians involved in direct patient care</td>
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<tr>
<td>Increase physician competence as flow physician</td>
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<td>Replace LPNs with RNs</td>
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<td><strong>Free staff</strong></td>
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<td>Move tasks outside the ED</td>
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<tr>
<td>Limit non-direct patient care activities to one physician</td>
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<tr>
<td>Schedule one extra consultant specialist during the day-time</td>
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<td><strong>Staffing</strong></td>
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<tr>
<td>Schedule changes</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>X</td>
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<tr>
<td>Increase physician staffing involved in direct patient care</td>
<td>X</td>
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<tr>
<td>Increase nurse staffing</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td><strong>Continual improvement</strong></td>
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<tr>
<td>Tools and practices for continual improvement</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>X</td>
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</tbody>
</table>

**Notes:**

- The computer in the room is used only by two physicians.
- An initial lack of senior surgeons at the ER in the flow physician role was temporarily overcome.

X, which specific changes were implemented in place at each ED service.
to understand and adopt this role. This led to the decision to employ more junior physicians in this role. At ENT-1, competence levels remained unchanged. In ENT-2, Peds-2, medicine, and surgery, LPNs were replaced by RNs to ensure that care teams had the competency and legal authority to complete the diagnosis-treatment process.

3. **Free staff.** To reduce workflow interruptions, ENT-1 moved competing tasks (such as telephone consultations) to staff outside the ED. ENT-2 and gynecology allocated an additional physician to the ED which allowed one of the two to be freed from competing tasks. Peds-1 and medicine scheduled an extra specialist so that one physician could be freed from competing activities to work as the flow physician.

4. **Staffing.** All services introduced schedule changes, shifting starting times to better match demand patterns. The two ENTs, gynecology, and Peds-2 increased the number of physicians involved in direct patient care from one to two. In ENT-1 and gynecology, this increase in staffing occurred when opening hours were reduced, independent of the lean intervention, from 24 h to 9 a.m.-4 p.m. In Peds-1, medicine, and surgery, care team physician hours decreased slightly as a result of staggered starting times. ENT-2, gynecology, and only initially Peds-1 increased nurse staffing. In Peds-2, independent of the lean intervention, there was a reduction of nursing capacity between 8 a.m. and 4 p.m.

5. **Continual improvement.** All services introduced a takt board, a computer-based tool to monitor the number of patients assessed by physicians per hour related to the anticipated pace of work, and a whiteboard to capture and manage improvement ideas at the ED. Process teams participated to regular meetings with the coaches and the hospital management team.

In addition to these five intervention areas, we also found evidence of demand management in the two services with limited opening hours (ENT-1 and gynecology). ENT-1 developed a flexible strategy where staff reviewed the queue and approximated how many patients they could see before closing and then stopped admitting new patients at a time point which ensured that all patients already in the queue would be seen. Gynecology stopped admitting new patients one hour before closing. Additional patients were asked to return the next day or to seek care at the other hospital site, open 24 h.

### Outcomes

Tables III and IV present an overview of the process performance before and after the implementation of the prototype as well as the performance levels during 2011. Comparing the results pre and post process prototype implementation, all services improved performance. Comparing 2011 performance, only three services (both ENTs

<table>
<thead>
<tr>
<th>Service</th>
<th>Before prototype implementation (%)</th>
<th>After prototype implementation (%)</th>
<th>Absolute change in percentage points</th>
<th>Relative change (%)</th>
<th>Performance level year 2011 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENT-1</td>
<td>77</td>
<td>93</td>
<td>16</td>
<td>19</td>
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<tr>
<td>ENT-2</td>
<td>73</td>
<td>90</td>
<td>17</td>
<td>23</td>
<td>92</td>
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<tr>
<td>Gynecology</td>
<td>69</td>
<td>90</td>
<td>21</td>
<td>29</td>
<td>90</td>
</tr>
<tr>
<td>Peds-1</td>
<td>66</td>
<td>79</td>
<td>13</td>
<td>19</td>
<td>76</td>
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<tr>
<td>Peds-2</td>
<td>82</td>
<td>85</td>
<td>3</td>
<td>3</td>
<td>79</td>
</tr>
<tr>
<td>Medicine</td>
<td>56</td>
<td>65</td>
<td>9</td>
<td>17</td>
<td>66</td>
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<tr>
<td>Surgery</td>
<td>57</td>
<td>64</td>
<td>7</td>
<td>12</td>
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</table>

**Table III.** Percentage of patients discharged within four hours.
and gynecology) achieved the four hour throughput target of 90 percent, and only one service achieved the waiting-time target of 40 minutes to first physician assessment (ENT-1). The SPC analysis showed that a systematic improvement in performance (percentage of patients discharged within four hours, and waiting time to first physician assessment) occurred in all services, either simultaneously with, or shortly after, the implementation of the lean process prototypes. Over time, three patterns emerged: large and sustained improvement where targets were met (ENT-1, ENT-2, and gynecology), moderate to large sustained improvement but without meeting targets (medicine and Peds-1), or an initial improvement which was not sustained (Peds-2 and surgery). An illustrative sample of the SPC charts is presented in Figures 1 and 2.

**Cross-case comparison**

Our analysis of the variation in impact of the lean program on performance across the seven services suggests that the difference in the number and type of mechanisms activated in each service may be a function of the complexity of the care process as defined by the number of interactions, iterations, and decisions typically required in patients’ care (Table V). Additional contextual factors related to organization (e.g. opening hours, unit size, educational commitments), person (e.g. heterogeneity and rotation of physicians involved in direct patient care), and technology (e.g. physical layout) could also be seen to influence the degree of complexity. Surgery, medicine, and both pediatrics exhibited more complex care processes than the two ENTs and gynecology.

**Process capability: how lean contributed to continuous patient flow and improvement in operational performance.** By comparing the CIMO configurations across the cases, we refined our mechanisms and arrived at four which could explain how operational performance was improved: match capacity with demand (through staffing, competency, and demand management), improve work process interaction, reduce non-value adding steps from a patient perspective, and improve the ability to coordinate care across organizational boundaries.

**How lean worked in less complex care processes.** ENT and gynecology were characterized by a diagnostic and treatment process often completed within the space of a single physician consultation, by lower patient volumes, with few patients in need of services from other units, by low admission rates, and by a small number of staff on each shift. The care processes were centered on the work of the physician who remained in the examination room and carried out most of the diagnostic and treatment procedures (Table V).

For the two ENTs, the lean program did not improve work process interaction, reduce non-value adding steps from a patient perspective, or improve the ability to

<table>
<thead>
<tr>
<th>Service</th>
<th>Before prototype implementation (minutes)</th>
<th>After prototype implementation (minutes)</th>
<th>Absolute change (minutes)</th>
<th>Relative change (%)</th>
<th>Performance level year 2011 (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENT-1</td>
<td>112</td>
<td>49</td>
<td>63</td>
<td>56</td>
<td>33</td>
</tr>
<tr>
<td>ENT-2</td>
<td>118</td>
<td>58</td>
<td>60</td>
<td>51</td>
<td>49</td>
</tr>
<tr>
<td>Gynecology</td>
<td>141</td>
<td>69</td>
<td>72</td>
<td>51</td>
<td>66</td>
</tr>
<tr>
<td>Peds-1</td>
<td>75</td>
<td>56</td>
<td>19</td>
<td>26</td>
<td>60</td>
</tr>
<tr>
<td>Peds-2</td>
<td>72</td>
<td>54</td>
<td>18</td>
<td>25</td>
<td>60</td>
</tr>
<tr>
<td>Medicine</td>
<td>89</td>
<td>49</td>
<td>40</td>
<td>50</td>
<td>55</td>
</tr>
<tr>
<td>Surgery</td>
<td>99</td>
<td>66</td>
<td>33</td>
<td>33</td>
<td>79</td>
</tr>
</tbody>
</table>

*Table IV.* Waiting time to first physician assessment

Complexity complicates lean
Figure 1.
Sample of I-charts for waiting time to first physician assessment with annotated prototype implementation and staffing changes.
Figure 2. Sample of P-charts for proportion of patients discharged from the ED within four hours with annotated prototype implementation and staffing changes.
### Table V. Characteristics of the care processes

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>ENT-1</th>
<th>ENT-2</th>
<th>Gynecology</th>
<th>Peds-1</th>
<th>Peds-2</th>
<th>Surgery</th>
<th>Medicine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of patients referred to radiology services</td>
<td>6.3%</td>
<td>6.2%</td>
<td>2.5%</td>
<td>12.3%</td>
<td>6.5%</td>
<td>30.1%</td>
<td>27.3%</td>
</tr>
<tr>
<td>Percentage of patients referred to lab services</td>
<td>14.3%</td>
<td>21.0%</td>
<td>25.4%</td>
<td>21.8%</td>
<td>50.6%</td>
<td>69.4%</td>
<td>82.2%</td>
</tr>
<tr>
<td>Average number of patients 0800-1600</td>
<td>14.4</td>
<td>18.9</td>
<td>16.1</td>
<td>27.0</td>
<td>19.9</td>
<td>25.9</td>
<td>36.6</td>
</tr>
<tr>
<td>Percentage of patients admitted per day</td>
<td>4.3%</td>
<td>6.9%</td>
<td>9.9%</td>
<td>15.5%</td>
<td>14.0%</td>
<td>24.5%</td>
<td>39.0%</td>
</tr>
<tr>
<td>Average number of admissions per day</td>
<td>0.62</td>
<td>1.30</td>
<td>1.59</td>
<td>4.19</td>
<td>2.79</td>
<td>6.35</td>
<td>14.27</td>
</tr>
<tr>
<td>Referral requirement to the ED</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Work organization</td>
<td>Physician remains in the examination room</td>
<td>Physician remains in the examination room</td>
<td>Physician remains in the examination room</td>
<td>Physician and patients move between rooms and units</td>
<td>Physician and patients move between rooms and units</td>
<td>Physician and patients move between rooms and units</td>
<td></td>
</tr>
<tr>
<td>Complexity of care process</td>
<td>Less complex</td>
<td>More complex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---
coordinate care across organizational boundaries. This suggests that these contexts were already organized with an approach akin to continuous flow and that matching capacity with demand was sufficient to achieve major performance improvements. The better match was the result of increased staffing, schedule changes, and increased physician competence (the last only for ENT-2). Not involving rotating physicians or students in direct patient care further improved continuous flow. ENT-1 further strengthened this mechanism through the demand management practice of limiting opening hours.

Similarly, gynecology improved the match between capacity and demand through staff and schedule changes and the development of demand management practices. Like the ENTs, gynecology did not find that RN/LPN-physician pairs improved work process interaction. Thus, two years after implementation, gynecology returned to the original way of working without specifying pairs. Instead, to improve interaction, the division of labor between midwives/RNs and doctors was more clearly delineated. Elimination of duplicate activities, standardization of the initial diagnostic process, and moving of equipment into the consultation rooms, reduced non-value adding steps from a patient perspective. Going beyond the recommendations of the coaches, gynecology also began to collaborate with units outside the ED and found that this improved the ability to coordinate care across organizational boundaries. Unlike the ENTs which excluded rotating residents and students from direct patient care, layout changes in the form of an extra room enabled rotating physicians and students in the gynecology ED to be involved in direct patient care without negatively impacting process performance. This was stipulated with an adequate physician capacity and after at least two weeks of on-the-job training.

How lean worked in more complex care processes. In the pediatrics, medicine, and surgery services, initial assessment can take time, diagnosis often requires support from external services, there is a higher admission rate with more patients, and a large rotation and proportion of junior and/or inexperienced doctors directly involved in patient care (Table V). While these four services improved (although only temporarily in two), informants from all four reported that more could be done to manage operations more efficiently. Medicine was never satisfied with the initial process prototype and subsequently developed and tested several different prototypes. Surgery and Peds-2 fell back to baseline performance (Figures 1 and 2) and surgery’s new process team had to again address the same problems that existed pre-lean.

Despite staffing increases and schedule changes, both pediatric services struggled to match capacity with demand. This was partially achieved in terms of daily demand patterns, but not with seasonal patterns. Surgery succeeded in matching physician but not RN capacity with daily demand patterns. The ability of all three services to change schedules was hampered by disagreements with union representatives and/or nursing management which prevented the changes from being implemented at some of the sites.

Surgery and both pediatrics found that when specialists served as flow physicians, the increased competency level allowed more active supervision of junior physicians to get assessment and case management correct from the beginning. Medicine discovered this caused new bottlenecks as junior physicians queued to consult the specialist. Peds-1 experienced a similar bottleneck, but still felt that the changes were an improvement. These bottlenecks suggest that the increased specialist competence was not sufficient to match capacity with the competency demands of junior physicians. For surgery, and Peds-2, matching capacity with demand through competency was impeded by specialists not freed from multiple and parallel tasks and/or when specialists did not follow the job descriptions for this role (e.g. being present at the ED).
Unlike the two ENTs and gynecology, prior to lean, staff from medicine, surgery, and the two pediatric services were frustrated by not being able to locate each other because of poor coordination, physical layout, and shift size. In this context, a care team approach and moving equipment into the examination room significantly contributed to improve work process interaction between team members. Work process interaction between junior physicians and flow physicians was, however, hindered when the latter had a high workload or were absent from the ED.

For medicine, diagnostic and treatment process standardization for the DVT flow reduced non-value adding steps from a patient perspective. Medicine and surgery also initiated collaborations with units outside the ED and found this to improve the ability to coordinate care across organizational boundaries. As for gynecology, this was done outside the recommendations of the coaches.

Learning capability: how lean helped staff to learn and continually improve

We found the same mechanisms linked to learning capability in all services: identify non-value adding time, visualize and identify problems in everyday work, develop concrete suggestions for improvement, and overcome organizational and hierarchical boundaries. Activation of these mechanisms did not, however, guarantee realization of a learning capability as defined by continual performance improvement.

Informants from all services agreed that the lean program helped identify non-value adding time, especially through the initial process mapping activities. Tools such as the takt board and the whiteboard helped visualize and identify problems (e.g. deviations from the prototype) in everyday work. However, in terms of design and usage, the tools were also problematic because they either inadvertently led to public shaming or because staff felt the information did not accurately reflect the situation on the floor. Some services used the tools repeatedly and focussed on identifying problems, but without staff engagement or evidence of root cause analysis:

Daily assessment [with the whiteboard] tends to be something one sticks to because one has to (PL2).

All services were able to apply the tools and practices to develop concrete suggestions for improvement. Still, most of the time the ideas for improvement were not systematically tested but rather implemented or rejected based on the opinions and personal experiences of staff or facilitators:

It isn’t systematic – much more ad hoc than they [the coaches] would want. If it feels good then we’ll go with it (PL1).

Staff involvement and engagement were hampered by poor alignment between the problems identified and the changes introduced (e.g. pediatric staff felt that a crucial problem was staffing levels after 4 p.m., but the changes adopted concerned other, lesser problems) and by a feedback system that did not return information to the right staff members. For instance, some services organized Friday meetings at the whiteboard to discuss problems identified during the week. But, due to staff rotation, those attending the meetings were seldom those who had identified or experienced the problems. This was compounded by high staff turnover rates among nurses in particular and by poor follow-up from unit managers.

Initially, the public engagement of the CEO in the lean work and the discussions at the management meetings (Table I) enabled process teams to overcome organizational and hierarchical boundaries making it possible to reallocate resources to the appropriate ED. However, decisions taken during the meetings were not always
implemented as managers were not directly involved in the improvement work or because they felt pressured to make spur-of-the-moment decisions without sufficient resources. The pressure experienced by the managers was partly due to the fact that the improvement teams reported directly to higher organizational levels. This led to conflicting loyalties for process leaders seeking to simultaneously live up to and placate the demands of different hierarchical levels:

The biggest problem is that as a process leader one should be loyal to hospital management and to the department. Hospital management wants us to report objectively. But the department feels that we are ‘telling on them’ (PL1). While evidence for the same active mechanisms and related challenges were found in all services, the two ENTs and gynecology were satisfied with the way lean impacted their operations because it fit with their local context and, for both ENTs, the way work had already been organized. This might have facilitated institutionalization of the changes. The way educational activities were integrated in these services, the small unit size that allowed staff to interact on a daily basis, and a larger proportion of stable staff involved in direct patient care, may also have facilitated institutionalization and thus sustainability.

Discussion
This in-depth comparative case study illustrates how the impact of the same lean-inspired changes to emergency services varied with the complexity of the care process. This has several implications for the design, implementation, choice of improvement goals and performance indicators, and evaluation of lean initiatives in emergency services.

*Develop process capability in healthcare*
For lean interventions to develop process capability, matching capacity with demand through staffing, competency, and/or demand management may be sufficient in less complex services. For more complex services, more sophisticated and encompassing lean interventions might be required, with efforts put into identifying and streamlining more differentiated patient streams and collaborating and coordinating across organizational boundaries.

The large improvements achieved by all emergency services during the first year suggest that despite heavy workloads and the fast tempo that often characterize emergency services, there is a great potential for improvement through increased performance awareness and the application of standard operations management principles, such as matching capacity with demand (Radnor and Walley, 2008; Langley, 2009). Improvements in capacity-demand matching were achieved either by adding staff or through changes in staff scheduling. But if the promise of lean is to do more with less (Womack and Jones, 2005), doing more with more or doing the same with more not only contradicts lean tenets, it is also a vulnerable practice in an era of budget constraints. This is especially so if healthcare organizations are not able to demonstrate that resources have been released through more efficient lean processes (Radnor and Holweg, 2010). As Øvretveit (2009) suggests, economic data should be included in quality improvement evaluations.

Simply adding capacity may not help to eliminate queues, and is needlessly costly, if this is not coupled with a clear understanding of capacity and demand variation (Silvester *et al.*, 2004). While many of the process leaders developed a more nuanced understanding of capacity and demand, the necessary staffing and scheduling changes
were not always implemented. Perhaps sufficient numbers of healthcare managers have not yet achieved the requisite level of operations management know-how or patient focus needed to motivate difficult decisions that challenge traditional ways of organizing work.

Capacity management is also achieved through competence management since differences in knowledge and skills impact capacity (Litvak and Long, 2000). Therefore, the level of performance variation in healthcare processes is a function of the clinicians’ experience levels, competence, and staffing (Lillrank and Liukko, 2004). Previous research has shown that increased competency levels at the ED improve patient and process outcomes (Geelhoed and Geelhoed, 2008). In contrast, our study suggests that the optimal level of competence needed will vary with the complexity of the care process and with educational commitments. The ENT-1 case, characterized by a less complex process, demonstrates that major improvements can also be achieved without increasing competence. Educational commitments were seen by some services as a barrier to flow efficiency. This led to the exclusion of students or staff-in-training from direct patient care which conflicts with this and many other hospitals’ educational mission. Gynecology invested in a layout change which allowed training to be conducted as a parallel work process without negatively impacting process performance. In fact, a two-week investment in training rotating residents contributed to improved performance. Anecdotal evidence suggests that increased competence and staffing had a positive impact on both patient and staff satisfaction. This type of effect, which is in line with the hospital’s rationale behind the lean program, suggests that measures beyond time-savings might be important for the benefit of both research and improvement.

Develop learning capability in healthcare

An organization’s learning capability is enhanced through the development of tools and practices that, when utilized daily, allow staff to learn from deviations from standardized practice and develop countermeasures to prevent their recurrence (Spear and Bowen, 1999; Spear, 2005). Fujimoto (1999) summarizes learning capability as a set of routines for problem identification, problem solving, and solution retention. We found evidence of several tools and practices for problem identification. Establishment of routines for problem solving and solution retention appeared, however, to be uncommon. There were no signs of continuous, iterative, data-driven, and timely improvement efforts integrated into the daily or weekly improvement routines. Similar challenges have been reported from experiences of applying lean in the NHS (Proudlove et al., 2008; Brandao de Souza and Pidd, 2011). This indicates the importance of improving the interactions between process improvement teams, staff, and managers, through for example, feedback systems that return performance information to the right staff in a timely fashion. A promising approach to integrate improvement activities into everyday work could be the use of ad hoc improvement teams, as has recently developed in gynecology, which gather relevant staff around immediate problems.

New organizational structures to obtain top management support and resource allocation are seldom described in the lean healthcare literature (Mazzocato et al., 2010; Holden, 2011). This case suggests that it is not enough to develop communication channels between the hospital management team and improvement teams. While the public and active involvement of the management team most likely contributed to the initial process performance gains, their exclusion from the problem identification and solving processes caused them to be held accountable by the CEO for changes which they were not actively involved in. Further research is needed to develop clarity about
the role that managers have in lean transformations and how leaders can best promote process and learning capabilities.

Methodological considerations
Our ability to detect the existence or the activation of the lean-related mechanisms was limited by the fact that we relied on post hoc interviews with involved improvement team members. Their involvement, especially considering the public disclosure of the different performance patterns, could negatively impact respondents’ ability to objectively make sense of the lean implementation program (Weick, 1995). We sought to counterbalance this through the teacher-learner approach of the realist interview. Instead of focusing on respondents’ feelings and experiences, the researchers helped respondents to understand and refine the CIMO configurations. This reflection was facilitated and enriched by the group approach which enabled respondents to compare their experiences, sharing and learning with each other, which served to deepen the analysis. Future studies could consider either direct observations or the development of quantitative indicators to independently appraise the activation of each mechanism.

We used several strategies to strengthen internal validity. Healthcare professionals from the improvement teams and strategic services development unit coaches were involved at several points in our data collection and analysis (Pawson and Tilley, 1997; Yin, 2009) and provided validation or suggestions for modifications.

We also developed a number of theoretical propositions that guided us in our explanation building (Pawson and Tilley, 1997). We developed different CIMO configurations, which (in some cases) could be replicated to explain similar or different performance patterns (i.e. literal or theoretical replication, respectively) (Yin, 2009). To strengthen literal or theoretical replication, more cases may be needed. However, the complexity of the interactions increases the possibility for unique configurations. For example, gynecology, with a degree of complexity similar to the two ENTs, appeared to have triggered several mechanisms whereas in the ENTs, only one mechanism was activated. Pawson and Tilley (1997), therefore, argue that replication may be less useful when evaluating complex interventions. Instead of generalization through replication as is typical for case study design, they recommend that generalization is achieved through cumulation whereby each additional case helps to further refine the configurations with their varying contexts. Our explanations could therefore be further strengthened through a new round of data collection with additional cases (Rycroft-Malone et al., 2010).

Conclusion
Applying a lean framework to emergency care, the services we studied demonstrated that even before going lean, the application of standard operations management principles such as matching capacity with demand can have a large positive impact on access to care. The variation in process performance and sustainability of the results observed demonstrates a much larger range of outcomes regarding the impact of lean interventions compared to the generally positive single-case descriptions predominantly found in the literature. Furthermore, this in-depth cross-case comparison indicates that care process complexity may be an important source of variation. While improving work process interaction, reducing non-value adding steps from a patient perspective, and improving the ability to coordinate care across organizational boundaries are all approaches that appear to be integral to developing a process capability, our analysis suggests that improvement efforts such as lean should be
carefully adapted to the complexity of the care process and to the educational commitment of healthcare organizations. Practitioners, managers, coaches, and researchers should therefore consider the specific characteristics of their healthcare delivery systems when they begin to design, implement, and evaluate process improvements. All these groups could also benefit from research that addresses the role of leadership in lean implementation efforts and the cost-effectiveness of process changes. Ultimately, the ability to adapt lean to a particular context and achieve continual improvement may depend on the development of (daily) practices that effectively support staff in reflecting on and learning from their work processes.

Acknowledgements

Author contributions: P.M., C.S., J.T. conceived of and designed the study. P.M. developed the structured interview guide and identified potential mechanisms which were reviewed and refined with U.B., C.S., and J.T. P.M. conducted the statistical analysis. P.M., C.S., J.T., and U.B. conducted the interviews. P.M. and C.S. analyzed the interviews, refined the CIMO configurations, and drafted the paper. J.T., M.B., and J.C. critically reviewed the manuscript. Additional critical comments beyond data and analysis validation were received from U.B., M.H., and F.J. All authors gave their final approval prior to submission of the manuscript. P.M. and C.S. are the guarantors of the paper.

The authors would like to thank Bo Herrlin, Anna Rasmuson, and the lean coaches at the Strategic Services Development Unit at the Karolinska University Hospital for granting us access to study the lean program and Johan Axelsson for support with the quantitative data collection. The authors thank all the health care professionals who participated in the interviews and who validated the data and interpretations. The authors thank the colleagues at the Medical Management Centre (Carolina Wanheden, Lisa Smeds, Sara Tolf, and Susanne Ullström) who took notes during the interviews. The authors thank Håkan Aronsson and Richard J. Holden for their valuable comments on a draft of the manuscript. The Swedish Vinnvärd program contributed to the salary of P.M.

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Appendix. Hypothesized mechanisms developed in phase 2 and tested in phase 3

Process capability:

(1) Lean (e.g. the prototype, the new roles of flow physician and flow nurse, the work descriptions, the streaming principles) has contributed to make the care process more clear in terms of content and execution, as well as reduced uncertainty about who should do what and when.

(2) Lean (e.g. care teams and care team rooms) has contributed to link care givers who are dependent upon each other in their work and thereby led to personnel (MDs, RNs, LPNs) more easily accessible for each other.

(3) Lean (e.g. care teams and care team rooms) has helped care givers to work more in parallel, i.e. to work with the same patient at the same time.

(4) Lean (e.g. flow physicians, flow nurses, and care teams) has contributed to the creation of a simpler and uninterrupted care process.

(5) Lean (e.g. flow physicians, flow nurses, and care teams) has contributed to caregivers having a better overview of what occurs at the ED.

(6) Lean (e.g. flow physicians, flow nurses, and care teams) has contributed to a better overview over where one’s colleagues are and where one’s patient is in the care chain.
Lean (e.g. flow physicians, flow nurses, and care teams) has contributed to increase the competence level at the ED and in that way increased the ability to provide the correct treatment/case management from the start.

(8) Lean (e.g. using a consultant as a flow physician) has contributed to make the consultant more easily available for less experienced physicians.

(9) Lean (e.g. care teams) has contributed to level the workload between care givers (physicians, consultants, RNs, LPNs).

(10) Lean has contributed to planning staffing levels and scheduling to match demand patterns.

(11) Lean has contributed to a better collaboration with the wards in terms of admitting patients to the wards.

Learning capability:

(12) Lean (e.g. process mapping and the prototype) has contributed to the identification of non-value adding time at the ED.

(13) Lean (e.g. the takt board and/or whiteboard) has contributed to make everyday processes as well as problems visible and thus increase understanding of how things work.

(14) Lean (e.g. the takt board and/or whiteboard) has contributed to make problems visible in everyday work and thus care givers can partake in quality improvement by generating suggestions for how work and the workplace can be improved.

(15) Lean (e.g. goals, measurements, improvement teams, prototyping) has contributed to the development of changes using a scientific approach: countermeasures are developed, tested, and eventually implemented.

(16) Lean (e.g. management meetings) opened up new communication channels through the hospital hierarchy which made it possible to pass and implement counter measures which otherwise had been impossible.

(17) Lean (e.g. process mapping, quality improvement principles and improvement group meetings) has contributed to the generation of concrete recommendations about how to organize work at the ED.

(18) Lean (e.g. process mapping, quality improvement principles and improvement group meetings) has contributed to generate suggestions about how to organize work tailored to the specific ED.

(19) Lean (e.g. improvement group meetings, whiteboard) has contributed to staff engagement in quality improvement and through this led to an increase in acceptance for those countermeasures that were implemented.

(20) Lean (e.g. management meetings) opened up new communication channels through the hospital hierarchy which made it possible to implement countermeasures which encouraged process thinking over silo-thinking – use the patient’s journey through healthcare and the corresponding needs that arise as the departure point.

(21) Lean (e.g. goals, measures, and the prototype) has contributed to create a shared mental model in the minds of all staff of where the organization is going.
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