Patient safety in the operating theatre: how A3 thinking can help reduce door movement

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Abstract

Issue. Research has often stressed the significance of reducing door movement during surgery for preventing surgical site infections. This study investigated the possible effect of a lean A3 intervention on the reduction of door movement during surgery in a university medical center in the Netherlands.

Initial assessment. A digital counter recorded door movement during 8009 surgical procedures during 8 months. The number of door movements per surgical procedure ranged from 0 to 555, with a mean of 24 door movements per hour across 26 specialisms.

Choice of solution. We aimed to reduce door movement in one operating room for orthopedic surgery by a lean A3 intervention. This intervention was executed by means of an A3 report that promotes structured problem solving based on a Plan-Do-Check-Act cycle.

Implementation. The steps of the A3 report were followed and completed one-by-one by a multidisciplinary team. The effect of the changes was monitored over the course of 12 months.

Evaluation. The use of a lean A3 intervention resulted in a sustainable decrease of door movements by 78%, from a mean of 24 to a mean of 4 door movements per hour during orthopedic surgery at one OR.

Lessons learned. This paper shows the relevance of and the possibility for a reduction of door movement during surgery by lean management methods in general and an A3 intervention in particular. This intervention stimulated dialogue and encouraged knowledge-sharing and collaboration between specialized healthcare professionals and this resulted in a thorough root-cause analysis that provided synergy in the countermeasures—with, according to respondents, a sustainable result.

Keywords: lean, A3 method, door movement, surveillance, monitoring, operating room

Introduction

To improve surgical safety, researchers have become increasingly interested in the influence of the surgical environment on surgical site infections (SSIs). In addition to the increasing mortality and morbidity caused by SSIs, as stressed by Burkitt et al. [1], SSIs are associated with excessive costs per infection that vary between €1000 per superficial SSI and €20 000 per deep SSI [2]; these costs refer to direct hospital costs such as prolonged hospitalization, additional diagnostics, medication and revision surgery [2]. SSIs have a significant impact on healthcare costs and an adverse impact on quality of care, which shows the importance of prevention interventions such as the Dutch safety management system that focuses on four major points of prevention: antibiotic prophylaxis, avoiding hair removal, perioperative normothermia and hygiene discipline.

Hygiene discipline as specified by the Dutch safety management system stresses the significance of limiting door movement during surgery. Although the direct impact of door movement on SSIs has not yet been supported by randomized studies, scholarly literature has demonstrated that traffic flow into and out of the operating room (OR) is an important factor in the development of SSIs; traffic flow, in turn, has been associated with door movement. For example, Lynch et al. [3] stressed the negative impact of a high rate of traffic
flow on the sterile environment of the OR, and door movement has also been correlated directly with an elevated level of airborne bacteria-carrying particles in the OR [4]. Additionally, door movement causes disturbance in the airflow as well as in the preservation of the necessary temperature during surgery [5]. Andersson et al. [4] therefore suggest that traffic flow patterns should be analyzed to reduce traffic flow into and out of the OR in order to prevent SSIs.

Research has demonstrated that lean, the term used to describe the principles and methods of the Toyota Production System that aims to preserve value with less work [6], can have a significant effect on traffic flow in the OR [7]. For example, the Exempla Lutheran Medical Center reduced door movement during surgery with the use of a 4-day rapid improvement cycle—a lean method [7]. This indicates that lean may also be effective for reducing door movement during surgery, and hence raises the question of whether other lean methods could help address this problem as well. For example, the A3 intervention, based on a Plan-Do-Check-Act (PDCA) cycle that promotes structured problem solving, is another lean method that is widely used [8–13].

Only a few studies have examined the effect of lean on door movement in the OR [3, 14–17], and no studies have discussed the reduction of door movement in the OR as an effect of an A3 intervention. This paper reports on the results of door movement monitoring during surgery in the OR theatre of a university medical center in the Netherlands. Moreover, this paper reports on the effects of an A3 intervention to reduce door movement.

**Methods**

**Setting**

This two-phased study was performed at the OR theatre of a 733-bed university medical center located in Amsterdam, the Netherlands. Approximately 16000 surgical procedures are performed annually in the OR theatre of this medical center. The OR theatre consists of 16 ORs in which we monitored door movement during surgery. Phase 1 of this study. The study's second phase, the A3 intervention, solely focused on door movement during orthopedic surgery performed in OR number 3. A multidisciplinary team of orthopedics was eager to start with lean, in context of lean implementation at the entire OR theatre, and their orthopedic operations were for the majority performed in OR number 3. This OR has four doors: the patient entrance, patient accompanist entrance, and the entrances to the scrub room and the setting room, which all differ in size and can all be opened and closed during surgical procedures.

**Phase 1: Monitoring door movement**

Over the course of 8 months, from June 2011 through January 2012, a digital counter recorded door movement during 9089 surgical procedures at the 16 ORs. The counter only recorded door movement during surgery; that is, from first incision until closure of the wound. The collected data for each door movement included date, time, sensor ID, door type and room number; the collected data for each surgical procedure consisted of the start- and end date, start- and end time, duration, room, specialist, specialist, operation code and operation name. Patient consent was not sought since no medical information was disclosed. Data were excluded for analysis if measurement errors of the monitoring system occurred or if a surgical procedure took <10 min. Eventually, our analysis was based on a dataset of 8009 surgical procedures. The data were subjected to a Pearson correlation coefficient between the variables; in addition, we drew a linear regression curve.

**Phase 2: Lean A3 intervention**

Parallel to door movement monitoring at the entire OR theatre, the effect of an A3 intervention on door movement was monitored for 12 months, from May 2011 through April 2012, in an OR for orthopedic surgery (OR3). The intervention used the A3 report: a method used by Toyota to capture the problem, analysis, improvement actions and action plan on a large sheet of paper, size A3 [18]. The A3 report was instituted for this study since it provides a methodical approach based on PDCA cycle to address and solve complex problems by a multidisciplinary team. It is one of the traditional tools of the Toyota Production System that is easily applicable to health care in contrast to for example the tool Single Minute Exchange of Dies, and is feasible for employees with very little time for actual problem solving. Moreover, the A3 report is a form of visual management that provides a framework for dialogical learning and embeds the change process, often visualized by a metric. The A3 intervention is characterized by various steps: clarifying the problem, specifying the current situation, determining the target condition, analyzing the root cause(s) and taking countermeasures [19]. These steps were completed one-by-one by a multidisciplinary team that consisted of an orthopedic surgeon, an anesthesiologist, a surgical assistant, a quality coordinator that was mentored by a lean coach during the entire period. The number of door movements—the intervention metric—was visible on a digital screen within the OR during each orthopedic surgical procedure. In addition, a printout of the door movements' weekly trend was visible opposite OR3 and was sent by e-mail to the team concerned.

**Results**

**Phase 1: Door movement at the OR theatre**

During a period of 8 months, a sum of 272 805 door movements was recorded in 8009 surgical procedures. An analysis of door movement per door type showed that 71% was concerned with the scrub room door, followed by the setting room with 24%. The patient entrance and the patient accompanist entrance caused 5% of the door movements.

The number of door movements per surgical procedure ranged from 0 to 555, with a mean of 32 door movements across 26 specialisms. The mean of door movements per hour
was 24; Fig. 1 shows the mean of door movements per hour plotted against five indicator surgeries as specified by the Dutch safety management system [5].

As can be deduced from the scatter plot in Fig. 2, there was a linear relation between the variables number of door movements and surgical duration (in minutes). Analyses of these variables performed on the data revealed a significant correlation ($r = 0.86$, $P < 0.01$); that is, as the duration of the surgical procedure increased, the number of door movements increased. No other variables approached significance in relation to door movement.

**Phase 2: The A3 intervention**

As prescribed in a previous section, the multidisciplinary team that was assembled for the A3 intervention firstly defined the problem—the possible consequences of door movement on patient safety, costs and quality of care—and subsequently investigated the current situation. The current situation showed that door movement of the scrub room door in OR3 occurred between 15 and 20 times per hour during surgery. The three other doors (the patient entrance, patient companion entrance and the setting room door of OR3) were deemed negligible for analysis. In addition, data analysis showed a difference between surgeons in the amount of door movement: a range of 10–27 door movements per hour, depending on the surgeon. After the team mapped the current situation, they defined the ideal state as zero door movements during each surgical procedure. They then determined the target condition to be zero door movements between the incision and closing of the wound, only allowing door movement for specific clinical reasons, namely a need for X-rays, unexpected materials, instruments or blood products; breaks or service shifts of employees; emergencies and/or supervision for the orthopedist or anesthetist.

In order to reach the target condition of zero door movements, the multidisciplinary team analyzed the gap between the current and the target condition with an *Ishikawa* diagram, also known as a fish-bone diagram or cause-and-effect diagram [20]. This diagram used the major categories people, machines, methods and materials to analyze the reasons for door movement. In total, the team identified 13 root causes and based on the *Ishikawa* diagram and subsequent dialogue specified 3 they felt required full attention first. Actions for improvement were taken for each of these three root causes (see Table 1).

![Door movements per hour](image1)

**Figure 1** Overview of the door movements of five indicator surgeries as specified by the Dutch safety management system: orthopedic, neuro, general, cardiac and gynecological surgery.

![Number of door movements versus surgical duration](image2)

**Figure 2** Number of door movements versus surgical duration in minutes.
The actions for improvement were implemented at the end of February 2012 and evaluated after 1 month in a plenary meeting by the team concerned. The metric showed a decrease of 78% of door movements to a mean of four door movements per hour during orthopedic surgery at OR3. Figure 3 shows the trend of door movement per hour during the total period of the A3 intervention and extended with a 6-month follow-up.

Table 1  Overview of three root causes resulting from an ishikawa diagram and the actions for improvement

<table>
<thead>
<tr>
<th>Root cause</th>
<th>Actions for improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unclearness among the OR team members with respect to the policy of entering and leaving during surgery</td>
<td>The orthopedic surgeons determine whether staff may walk out of the OR during surgery&lt;br&gt;Prior to the start of this measure, a meeting with the head of orthopedics, the head of the OR and all orthopedists was set up to discuss the implementation of this measure. All OR staff and anesthesiologists active in OR3 were informed by e-mail prior to this measure. Per 1 March 2012 the measure was put in progress at OR3 for orthopedic surgery</td>
</tr>
<tr>
<td>The telephone number used within OR3 was not visible outside the OR for OR staff. As a result, the door had to be opened for communication</td>
<td>The right telephone number used within OR3 was made visible outside the OR&lt;br&gt;Revision of the warning sign that is suspended at the door of OR3</td>
</tr>
<tr>
<td>The team experienced the warning sign not to walk in during surgery as not powerful enough</td>
<td>Revision of the warning sign that is suspended at the door of OR3</td>
</tr>
</tbody>
</table>

Figure 3  The trend of door movement per hour during the total period of the A3 intervention and extended with a 6-month follow-up.

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Discussion

This study aimed to assess the use of an A3 intervention in the reduction of door movement during surgery in a Dutch university medical center. The first phase of this study revealed that all surgical specialisms dealt with a relatively high number of door movements per hour \( (n = 24) \); the second phase showed that the number of door movements reduced with the use of the lean A3 method: during orthopedic surgery, the number of door movements decreased by 78%.

The study results should be interpreted in context and require follow-up research. The A3 intervention was applied in one OR—used for orthopedic surgery—in one institution. While this limited context does indicate the possible effectiveness of lean, further research is required to establish a more comprehensive notion of the use of the A3 intervention for the reduction of door movement. For example, as this study was not designed to investigate the causal relationship between door movement and SSIs, statistical analysis on SSIs was not feasible; future studies could incorporate medical information.
to help gain a more comprehensive understanding of the impact of door movement on SSI. However, despite its contextual limitations, this study does indicate a need for a reduction of door movements in OR theatres in order to reduce the risk of the development of SSIs. In addition, our A3 intervention offered a valid result: a reduction of door movements by 78%.

Our study shows that all specialisms at the medical center dealt with a relatively high number of door movements per hour (n = 24). This result corroborates with previous findings of the studies of Parikh et al. [15], who reported on ~40 door movements per hour for pediatric orthopedic surgery; Andersson et al. [4], who reported a door movement rate of 12.9 per hour for full-length orthopedic trauma surgery; Young et al. [16], who reported a mean of 19.2 door movements per hour for cardiac surgery and Lynch et al. [3], who reported a door movement rate of 5–87 per hour for cardiac, orthopedic, neuro, plastic and general surgery. Door movement is a focal point of attention for the Dutch health inspectorate, as is evident from the numbers it allows for door movement in its audits: >5 = insufficient, 3–5 = moderate, 2 = sufficient, 0 = good [21]. The high rate of door movement during surgery we found may therefore support the decision of the Dutch health inspectorate to make door movements a focal point in the category hygiene discipline of the Dutch safety management system, as our results indicate that the actual amount of door movement far exceeds the targets set by the inspectorate.

An important finding of our study was the reduction of the number of door movements by 78% (note: an average of 4 door movements per hour) as a result of the lean A3 method. This method led to a clear problem statement and a description of the then current situation. As the next step of an A3 intervention prescribes, the team collectively determined a feasible target condition. Next, the gap between the target condition and current situation was unraveled by an in-depth analysis using an Ishikawa diagram. This analysis showed three major root causes: unclear policy regarding entering and leaving during surgery, not possible to communicate by telephone and an unclear warning sign not to enter the OR during surgery. This root-cause analysis resulted in three major actions for improvement, which resulted in a sustainable reduction of door movement.

Previous studies have addressed the importance of interventions on door movement [3, 4, 15, 16]. These studies suggest improvement of parts, as for example the use of a warning sign or automatic door counters, and recommend future studies to analyze reasons for door movement as this has been hypothesized to be a requisite for the success of an intervention. Lynch et al. [3] noted that common reasons for door movement were personnel entering or leaving for breaks, information issues and supply issues. These reasons were also identified in our Ishikawa diagram, yet the main root cause seemed to be unclearness among the OR team members with respect to the policy of entering and leaving during surgery. As the surgeon is held responsible for the outcome of surgery, which includes SSIs, a learning process among our team members led to the conclusion that the surgeon is primarily responsible for the reduction of door movement during surgery. As a result of this learning process, the team members determined this responsibility clearly to be one of the surgeons. This could be considered the major factor in the sustainable decrease of door movements during surgery in our study: clearly assigned responsibilities. Two other root causes this study discerned seem to be supportive measures: we postulate that the door counter can be used as a tool to help monitor and visualize improvement and the warning sign as a constant reminder for all employees in the OR theatre. These tools thus support the creation of a shared sense of responsibility of the team that supports the surgeon’s lead. The measured effect of this combination of improvement activities provides support for the premise that a root-cause analysis leads to an in-depth debate among healthcare professionals and that synergy—rather than a focus on parts—fosters sustainable improvement.

In general, our findings suggest that structured problem solving with an A3 report in a team may be seen as a dialogical process which alters behavior, either directly or indirectly. This supports the idea of the Dutch safety management system that debates about traffic flow may contribute to behavioral change [5]. The A3 report in this study consisted of steps that stimulated dialogue and encouraged knowledge-sharing and collaboration between colleagues to reduce door movement. Although this was not part of this study, the A3 intervention may in fact have resulted in an increased awareness of our healthcare professionals. In our case it even resulted in surgical procedures without any door movements, but this occurrence of zero door movements can also be due to the short duration—yet never shorter than 10 min—of the surgical procedures included in our study. Parikh et al. [15] reported that if the total surgery duration increases, the maximum number of personnel in the OR increases, which, in turn, increases the total number of door movements; we found a similar positive correlation between surgical duration and door movement. More research is needed to add to a general understanding of the association between A3 thinking, behavioral change and learning theories, but our results suggest that by providing an infrastructure in the form of an A3 report, the learning process between various health professionals has been encouraged.

**Conclusion**

This paper shows the relevance of and the possibility for the reduction of door movement during surgery by the lean A3 intervention method. We conclude that the reduction of door movement can be achieved by the use of lean methods: this study focused on an A3 intervention and showed a sustainable reduction of door movement by 78%. In addition, we found that the A3 intervention stimulated dialogical learning and encouraged knowledge sharing and collaboration between various specialized healthcare professionals. This resulted in a thorough root-cause analysis that provided synergy in the countermeasures—with a sustainable result. The successful effect of an A3 intervention in reducing door movement could be usefully explored in further research.
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References