Implementing Lean Principles in the Healthcare Industry: A Theoretical and Practical Overview

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1 Introduction

Healthcare industry has a relatively high proportion in the developed countries' gross domestic products (GDP) in the last six decades, and the USA has been shown to have the highest level of health spending in the world (c.f. Borger et al. 2006; Congressional Budget Office). As stated by McLaughlin and Olson (2012), the share of healthcare expenditures in GDP is expected to be 19.6% by 2019 in the USA (CMS 2010). Taking into consideration the rising demand for improved healthcare and decreasing costs, both healthcare providers and managers in the micro level, as well as healthcare policymakers in the macro level, strive to figure out how to improve healthcare outcomes for all stakeholders. In this regard, lean principles have been shown as one of the most future-promising means by several parties in the healthcare industry (c.f. PCAST Report 2014; Womack et al. 2005; Caldwell et al. 2005; Chalice 2005). President Obama's healthcare plans strongly mentioned the necessity of implementing lean in the nationwide healthcare system (PCAST Report 2014).

Lean principles were successfully implemented in other industries after Toyota originated lean in the automobile industry (c.f. Laursen et al. 2003; De Souza 2009; Liker 2004). A great variety of industry has benefited from lean by reducing

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waste and increasing reliability, quality, and overall performance (Chalice 2005; Womack and Jones 1996; Womack et al. 2005; PCAST Report 2014). Additionally, Collins et al. (2015: 906) state that “despite the differences in organisation and technology, the challenges of achieving quality and cost advantages are quite similar in both manufacturing and healthcare.” Similarly, many theoretical and practical studies have shown that lean can be implemented in healthcare to increase the overall performance, particularly by reducing and eliminating waste in various services (c.f. Manos et al. 2006; Miller 2005; Shahrabi 2015; Berwick et al. 1991; Zidel 2006). However, no systematic effort to provide an approach to integrate 14 lean principles in healthcare service delivery processes has been made so far. Instead, with misunderstandings and lack of knowledge of preconditions for lean implementation (Dahlgaard et al. 2011), lean practitioners in the healthcare industry adopted lean tools in several processes which results in very limited outcomes. Gomez et al. (2010) pointed out that by optimizing only one process in the entire value chain, sub-optimizing components would be at risk, and eventually the entire value chain. Implementing lean in an isolated process would be detrimental for the sake of the lean efforts in healthcare organizations. Based on these facts, the main objective of this chapter is to present how 14 principles of lean can be implemented in healthcare delivery processes. De Souza (2009: 121) points out that “it remains a challenge for academics and practitioners to evaluate lean healthcare under a more critical perspective.” Based on the outcomes of this study, healthcare providers, managers, and decision-makers can focus on how to implement lean in healthcare organizations more effectively and efficiently.

This chapter flows as follows. The next section details lean principles and analyzes how to interpret lean in healthcare organizations. The limitations are followed by the conclusion.

2 Lean Principles in Healthcare Processes

While Rosmulder (2011) addresses that healthcare delivery does not equal industrial mass production, Allen (2009) expresses that the hospital industry stayed behind other industries in terms of adopting the concepts of operations management. Besides, service chain management in the healthcare setting is built on particular components that make it hard to adopt what other industries accomplished (Rust 2013). Literature also emphasizes the fact that healthcare processes are not designed as to meet higher efficiency and effectiveness expectation, which results in prolonged waiting and processing times, duplication of services, transportations, and operations, and eventually delays and increased adverse events and medical errors (c.f. Manos et al. 2006). According to Frings and Grant (2005: 314), “defects in patient care processes can run the spectrum from minor dietary issues to patient morbidity and fatality” or from transfusion mistakes to incorrect amputations (Kumar and Steinebach 2008). In a general spectrum, errors and mistakes in healthcare can be detrimental and devastating to all parties since human life is at risk (Taner et al. 2007). As reported by Kohn et al. (2000), nearly 98,000 patients admitted to hospitals lost their life because of preventable medical errors and nosocomial infections. Wagner (2004) identifies in-hospital errors as one of the leading killers in the USA. These facts make healthcare organizations as a candidate to integrate operations management to improve overall performance. In this sense, lean philosophy is presented as one of the effective ways in healthcare organizations (c.f. Womack et al. 2005).

Due to the nature of prioritization of the healthcare services that are based on (1) not harming patient and (2) improving patient's health conditions at any costs, ineffective managerial outcomes have not been attractive to the managers, as long as the patient's health conditions are improved. Similarly, healthcare processes are characterized to save human lives in a service delivery environment where many unpredictable risks are high (Tu et al. 2009). However, increasing costs, preventable medical errors, demanding healthcare providers and customers, and raising quality and performance expectations resulted in searching how to improve the outcomes of processes. In a great variety of industry, it is expected to decrease cost while increasing quality and efficiency. The increasing cost of healthcare has been correlated with the inefficient use of resources and non-optimized processes (Arcidiacono and Pieroni 2018). Based on that, lean was perceived as a remedy for the aforementioned concerns in the healthcare industry. The roots of the lean are built upon creating *value* for customers by eliminating waste and variation (c.f. Womack and Jones 1996; Gomez et al. 2010; Liker 2004). In a broader point of view, Radnor et al. (2012: 5) identify lean as:

> a practice based on the philosophy of continuously improving processes by either increasing customer value or reducing non-value adding activities (Muda), process variation (mura), and poor work conditions (muri).

Wickramasinghe et al. (2014) identify the quality of care as meeting the physical, psychological, and social expectations of patients who search for care. Institute of Medicine (IOM) focused on six aims such as safe, effective, patient-centered, timely, efficient, and equitable care. From IOM's perspective, each aim is likely to be achieved based on lean. Similarly, Husby (2012) addresses that if enough resources, discipline, and long-term focus are devoted, lean would be successfully implemented in healthcare, where there is high variability in the processes. According to Black and Miller (2008) and Barnas (2011), lean has already been utilized in the US healthcare system over the last decade. Lean principles are manifested that create a new way of management thinking. On one hand, healthcare is often identified as badly managed (Machado and Leitner 2010) and the ultimate negative outcome is considered the preventable death of a patient (Black and Miller 2008). On the other hand, lean seems more adaptable to healthcare settings based on examples (De Souza 2009) to eliminate the roots of bad management. As a starting point, De Souza (2009: 132) states that "lean healthcare is still in an early stage of development if compared to the same process in the auto industry." Jonsson and Randefelt (2013: 3) point out that "lean is regarded as a solution for many issues connected to healthcare." Lean in healthcare has also been gaining popularity among practitioners and decision-makers not because it is a "management fad," but because it produces sustainable results in healthcare.

The lean philosophy and norms/values in healthcare have many crucial similarities. As a general rule, it is aimed at "doing the right thing at the first time" in lean (Liker 2004). This fundamental rule is centered at the heart of medicine. Due to the fact that healthcare processes cannot tolerate mistakes, delays, and errors, it naturally fits in healthcare. Lean in healthcare is expected to "remove duplicates and unnecessary procedures such as recording patient details in multiple places; excessive waiting for staff; and uncoordinated discharge processes resulting in a longer length of stay" (NHSIII 2007). Specifically, lean in healthcare is commonly used to minimize delays in the emergency rooms, reduce the number of return visits, eliminate medical errors, and prevent inappropriate procedures (Rust 2013: 25).

In the healthcare world, there are good examples of lean. For example, De Souza (2009) and Burgess (2012) addressed that USA, UK, and Australia are countries in which healthcare successfully implemented lean with an expectation of improving overall performance. Similarly, Kollberg et al. (2006) and Jonsson and Randefelt (2013) presented how the Swedish healthcare system developed a measurement system, the "flow model," to reduce lead and waiting times. Kollberg et al. (2006), Karlsson et al. (1995), and Womack and Jones (2003) mentioned how lean is implemented in healthcare, emphasizing that patients should be the first priority, and time and comfort are the key performance indicators. Focusing on identifying "customer" in healthcare, Young et al. (2004) state that lean may benefit healthcare processes. Additionally, Womack et al. (2005), Graban (2009), Black and Miller (2008), Tachibana and Nelson-Peterson (2007), and Breyfogle and Salveker (2004) support the implementation of lean in healthcare.

Translating lean into healthcare has been challenging (Rust 2013: 85). Before starting the lean journey in healthcare, a comprehensive definition of "customer" should be made. Kollberg et al. (2006), Machado and Leitner (2010), and Bushell and Shelest (2002) suggest that the primary customers of the healthcare outcomes are patients. Frings and Grant (2005) consider patients and healthcare service providers as the primary customers. From the financial aspect of healthcare, Kollberg et al. (2006) also consider patients' families, payers, the society in general, and medical students.

Attempts in the use of lean in the healthcare arena remains primarily in smaller, lower-level processes. A literature search for the clinical implementation of the lean indicates sparse publication of its use in the provision of healthcare (Raja et al. 2015; Sugianto et al. 2015; Lunardini et al. 2014). A review of hospitals in England likewise demonstrated that implementation tended to be isolated rather than system-wide (Burgess and Radnor 2013). However, their review of a second dataset projecting lean implementation trajectory across time signaled lean's increasing use by English hospitals and shows progression toward an increasingly systemic approach. In one of the clinical studies of lean in a multicenter examination comparing a variety of approaches to lean, Van Vliet et al. (2011) examined the entire process of moving a patient with a cataract from diagnosis to recover after phacoemulsification. Their publication provides an excellent example of the

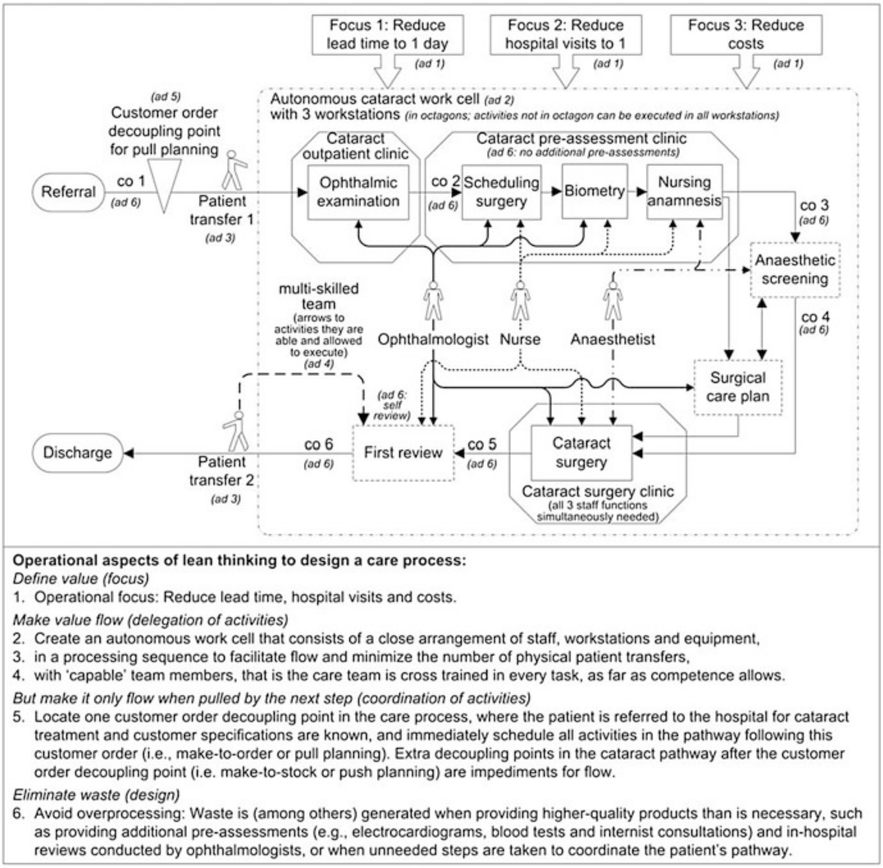

Fig. 1 Example of lean framework for a cataract removal pathway (Van Vliet et al. 2011)

schematic formulation that is inherent in lean process exploration (Fig. 1). The authors concluded that reducing non-value-added parts of the process appeared to have a stronger influence on improving efficiency than other lean thinking principles.

Some limited studies indicate that concerted lean effort in a limited scope can improve performance. Sugianto et al. (2015) applied lean in processing gastrointestinal biopsy and reduced total time from tissue input to results output by 63%. Lunardini et al. (2014) implemented lean principles to optimize instrument utilization for spine surgery in an effort to standardize instruments and reduce costs. Based on the data and stakeholder consensus, about 40% of the instruments were removed, resulting in a significant instrument set weight reduction and consolidation of two instrument sets into one, with $41,000 cost savings annually. Warner et al. (2013) brought lean to a more multifactorial process, namely, on-time first case vascular surgery starts, and employing DMAIC methodology and a Rapid Process

Improvement Workshop, rapidly improved the proportion of patients arriving on time to the OR. Their results were sustained at 1 year. However, improvement in opportunity costs reached only $12,582 in the first 9 weeks.

In addition to positive outcomes, published results reveal several difficulties in implementation of lean in clinical areas, due to the lack of exposure to these specific principles in the education and experience of managers (Raja et al. 2015). Raja et al. (2015) stated that in a study of implementing an automated process issue reporting system, the implementation of a QI reporting system from psychiatry residents met several limitations. Given the high volume of issues raised and limited resources, this reporting system informally promoted “lean” principles of waste identification and continuous improvement. The authors categorized residents’ reports as closely as possible into lean categories of operational waste. The resident’s submitted issues were completely addressed with the requested outcome partially or fully implemented or with successful clarification of existing policies in over 80% of cases. The authors concluded that a real-time, voluntary reporting system can effectively capture trainee observations of waste in healthcare and training processes and help contribute to meaningful operations improvement.

Although somewhat pessimistic in tone, but at least displaying some realism, Waring and Bishop (2010) examined and commented on three domains regarding the lean process: Rhetoric (platitudes and slogans), Ritual (the practice), and Resistance. They concluded that some of the inconsistencies found in current healthcare improvement efforts might result, in part, from the poor translation of models and methodologies developed in other settings (e.g., automobile manufacturing), that gives inadequate attention to current practices and potential unintended consequences. In addition, a lack of social and cultural research explores lean implementation and interaction with existing clinical practices. They suggested that making healthcare services lean is likely to be a process fraught with resistance and battles, as it becomes reinterpreted and reshaped by different social actors to ensure that it fits with their prevailing vision or aspirations for clinical practice. As such, it enters into an environment rife with conflict and disagreement, and unlikely to migrate to practice fully intact.

In continuous quality improvement efforts, the impact of IoT (Internet of Things) on lean in healthcare processes is another factor for healthcare providers and designers to be considered. With all algorithms and intelligent systems, IoT will take a role as a game player in the healthcare industry, since its capability of reducing cost and improving quality of care. According to Scarpato et al. (2017), IoT has become a fundamental technology in the medical environment. In the same vein, wired and wireless components of IoT can be expected to function as critical actors in lean, particularly in increasing the value of processes and detecting and decreasing adverse events, errors, failures, and abnormalities. As a paradigm shift, IoT takes a place in Industry 4.0 revolution (Löffler and Tschiesner 2013). The fact that IoT is expected to link all related activities in the manufacturing setting, such as logistics, supply chain, and manufacturing, the same positive effect of IoT in healthcare processes is likely to be active. As stated by Bhatt and Bhatt (2017), “the reason for integrating healthcare with the Internet of Things features into medical devices improves the quality and effectiveness of service, bringing especially high value for elderly, patients with chronic conditions and those that require consistent supervision.” The overall positive effects of reduced inventory throughout the healthcare industry, including hospitals, clinics, suppliers, pharmaceutical, and biomedical device manufacturers, may be strengthened by IoT practices. As the main two components of IoT, value creation and cost reduction (Löffler and Tschiesner 2013) take critical roles in lean implementation in healthcare organizations. Parallel to IoT, Big Data should also be considered in the healthcare industry to increase lean performance, specifically on data collection and analysis needs in lean implementation.

Hines et al. (2004) and Radnor et al. (2012) stated that lean in healthcare would be of a limited impact and largely confined to the application of specific tools to local optimization. According to them, lean in healthcare will go through a similar evolution to lean in manufacturing: from shop-floor-based tools to a process view and a holistic understanding of pathways. In Liker and Convis’ (2011) book, the lean philosophy is constructed on 4P model, which includes *philosophy*, *process*, *people and partners*, *and problem-solving* (Table 1). Each level in 4P model includes several items of 14 principles (Liker and Convis 2011; Womack and Jones 1996). In light of the 14 principles, the next subsections analyze how to incorporate and interpret them in healthcare.

Table 1 Liker’s (2004) 14 principles

Group	Principle
Philosophy: Long Term	1. Base your management decisions on a long-term philosophy, even at the expense of short-term financial goals
Process: Promote Flow – create a pull production system that has continuous flow and balanced workload	2. Create a continuous process flow to bring problems to the surface 3. Use pull systems to avoid overproduction 4. Level out the workload (*heijunka*) 5. Build a culture of stopping to fix problems, to get quality right the first time 6. Standardized tasks are the foundation for continuous improvement and employee empowerment 7. Use visual control so no problems are hidden 8. Use only reliable, thoroughly tested technology that serves your people and processes
People: Respect and Development	9. Growing leaders who thoroughly understand the work, live the philosophy, and teach it to others 10. Develop exceptional people and teams who follow your company’s philosophy 11. Respect your extended network of partners and suppliers by challenging them and helping them improve
Problem-Solving: Continuous Improvement– organize their continuous improvement activities	12. Go and see for yourself to thoroughly understand the situation (*genchi genbutsu*), 13. Make decisions slowly by consensus, thoroughly considering all options, and implement decisions rapidly 14. Become a learning organization through relentless reflection (*hansei*) and continuous improvement (*kaizen*).

2.1 Philosophy

Principle 1: Base your management decisions on a long-term philosophy, even at the expense of short-term financial goals
In lean, Liker (2004: 37 & 73) focuses on generating value for the customer, society, and the economy by stating that, "*do the right thing for the company, its employees, the customer, and society as a whole*." Jonsson and Randefelt (2013) propose that the value formulation is perceived as a guide to carrying the organization toward the desired direction. Collins et al. (2015) suggest that the concept of converting raw materials to a product creating value to the customers is equally significant in healthcare.

Womack and Jones (1996: 141) express that "... failure to specify value correctly before applying lean techniques can easily result in providing the wrong product/service in a highly efficient way – pure *muda*." Radnor et al. (2012) point out the importance of identifying "value" and "waste" from a customer's point of view in the process. Liker (2004: 77) points out that "Toyota believes this is what drives profit in the long run." According to Gomez et al. (2010) and Rust (2013), "lean is centered on creating value for the customer with less work." Manos et al. (2006) address that value adding for patients is different for customers of the production systems since healthcare processes are focused on prevention or cure. While literature (c.f. Rosmulder 2011; Rust 2013) focuses on the diagnostic question "is the customer willing to pay for the product/service?" lean in healthcare should start with the definition of value (Gomez et al. 2010). While answering this question, complexity in healthcare processes increasing risk and inefficient use of resources (Rust 2013) should be taken into consideration. However, there are many points in which creating value depends on other processes that do not have a value at the first glance. For example, the value-added processing time may be around 30 minutes while turnover time takes at least 45 minutes or longer in an ENT case in the operating room (OR) (Pakdil and Harwood 2005). From a value-added perspective, the turnover time might be perceived as a non-value-added time even if significant tasks are performed in this sub-process. "The value produced is more or less untouchable, difficult to specify and unclearly priced" (Rosmulder 2011: 2). Value is created indirect interaction with the patients (Rosmulder 2011: 19). Similarly, Radnor et al. (2012) address that the lack of customer and value definition blocks quantifying the productivity and quality improvement efforts.

The lack of value definition affects diagnosing potential wastes and how to implement lean in healthcare. Liker (2004) points out that most business processes are 90% waste and 10% value-added work. Graban (2009) states that healthcare organizations implementing lean focus only on the elimination of waste by ignoring the core of lean, smoothing flow, and improving workplace environments and conditions. In a similar vein, Robinson et al. (2012) state that healthcare organizations focus only on eliminating waste and cost reduction by neglecting system-wide variation reduction efforts.

By integrating a management system focusing on value identification, committed workforce, having the constancy of purpose, and doing the right thing for the customers, healthcare organizations get ready to implement long-term orientation in the first principle's requirements. Robert McCurry states that "the most important factors for success are patience, a focus on long-term rather than short-term results, reinvestment in people, product, and plant, and an unforgiving commitment to quality" (Liker 2004).

2.2 *Process*

Liker (2004: 87) expresses that "Toyota leaders truly believe that if they create the right *process* the results will follow." A process is identified "as a set of actions or steps each of which must be accomplished properly in the proper sequence at the proper time to create value for the patient" (Miller 2005). The following principles, principle 2 through 8, are comprised of the details of the "process" segment of lean.

Principle 2: Create a continuous process flow to bring problems to the surface Liker (2004) states that "flow" is at the heart of the lean and that decreasing the elapsed time leads to best performance based on highest quality, lowest cost, and shortest delivery time. Liker (2004) also addresses that lean journey should start with creating continuous flow wherever applicable in the core processes. More importantly, flow efficiency is utilized as an indicator measuring the ratio of how much a unit is processed from when a need is determined to when the need is met (Modig and Åhlström 2012). However, Jonsson and Randefelt (2013) address that it is harder to figure out how the flow is built in non-production businesses. Jonsson and Randefelt (2013) see the point of allocating activities in separate departments as problematic to maximize effectiveness, which results in increasing waste throughout the system. This point is also seen as a contradiction with one-piece flow rule in lean.

The understanding of continuous process flow implemented in manufacturing settings cannot be directly adopted in healthcare due to the nature of uncertainty and unexpected conditions of healthcare services. In the manufacturing setting, when the customer places an order, the process starts obtaining raw material and operationalize just for meeting that customer order. In this sense, uncertain or unplanned patient visits may result in deficiencies in continuous flow Kollberg et al. (2006). The identified customer demands in various sections may vary based on test results and diagnoses, affecting continuous flow and smoothing of the flow. As an example, Frings and Grant (2005) point out that inefficient hospital discharges result in a great variety of low performance in terms of the increased bottleneck, capacity issues, and dissatisfied parties in healthcare delivery processes. In this sense, continuous discharge process is capable of bringing bottlenecks and issues to the surface in inpatient clinics.

In the manufacturing setting, lean is built upon U-shaped production lines with all required equipment and multiskilled employees in order to catch the *takt* time.

In healthcare, patient rooms in clinics or ORs can be considered U-shaped service delivery line. Looking into services and care in this perspective, it can be perceived that patients, biomedical equipment, information, etc. are automatically supposed to be transferred from one point to another within designated cycle time.

This principle is most easily applied to processes in which repetitive pathways occur. As mentioned earlier, healthcare administrators and clinicians have generally not thought of the care to patients they provide as analogous to automobile manufacturing. The argument used has frequently centered on the concept that a "human is not a car," and too many variables are inherent in clinical care to analyze it systematically. However, due to the rising costs of healthcare (>20% of GDP) and better education needs in efficiency, it is seen that many care processes are repetitive. To accurately map a system, one must obtain high-fidelity and reliable data about the flow of information. Accurately timing steps and determining multi-departmental teams, if necessary, is essential to obtain a true picture of the processes. To map a patient's path to treatment (the value chain) and identify areas for improvement, a current state map can be created in a tool such as a value stream map (VSM). For example, let's use a process in which the first step a patient takes is to visit his primary care physician about a lump in his groin (Fig. 2). The time the patient spends at any step can be broken down into value-added (VA) and non-value-added (NVA) cycle times. VA is the time the customer is willing to pay for: for example, the 20 minutes spent consulting with the PCP. NVA is the time the customer is not willing to pay for. Items such as spending 45 minutes in the waiting room (see the yellow-colored process) or having blood work drawn for a chemistry panel the patient already had a month ago (see the red-colored process) would be considered

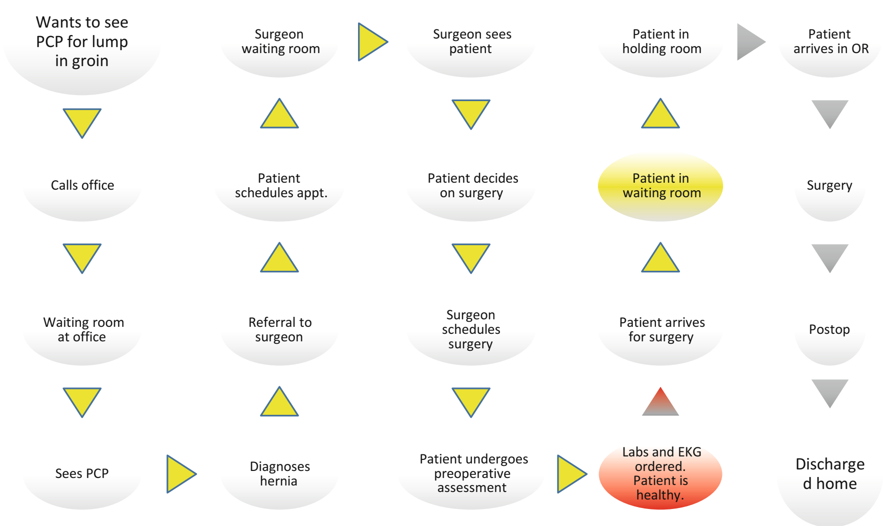

Fig. 2 A healthcare delivery process flow chart

NVA resource utilization. The pointer between process steps is called a "push" arrow. This shows that once a patient completes a step, they are "pushed" to the next step. This is inefficient, and a more efficient process can be designed by changing push steps to continuous flow or "pull" steps. The yellow triangles indicate the time a patient spends waiting for the next process. These steps are non-value-added actions for the patient.

Damle et al. (2016) determined that VSM could work in a clinical setting such as an endoscopy unit (Fig. 3). With no higher utilization of resources, a single lean process improvement cycle increased their productivity and capacity of their colonoscopy unit by 10%. The authors expected this to result in increased patient access and revenue while maintaining patient satisfaction.

By identifying all the steps, one can begin mapping the entire process, moving from left to right. Once the system is mapped out, the prototypical future state map is created, with the possibility that one could add more detailed microstates within larger streams (Fig. 2). Stream mapping in healthcare can become very complex and detailed. These maps can identify areas for improvement, and once implemented, users can update them, producing more "current state" maps as part of an iterative quality improvement process. At its most basic use, VSM can guide users in strategic directions. Potentially, with the increasing use of artificial intelligence, we can work toward employing these complex maps for use in daily tactical planning

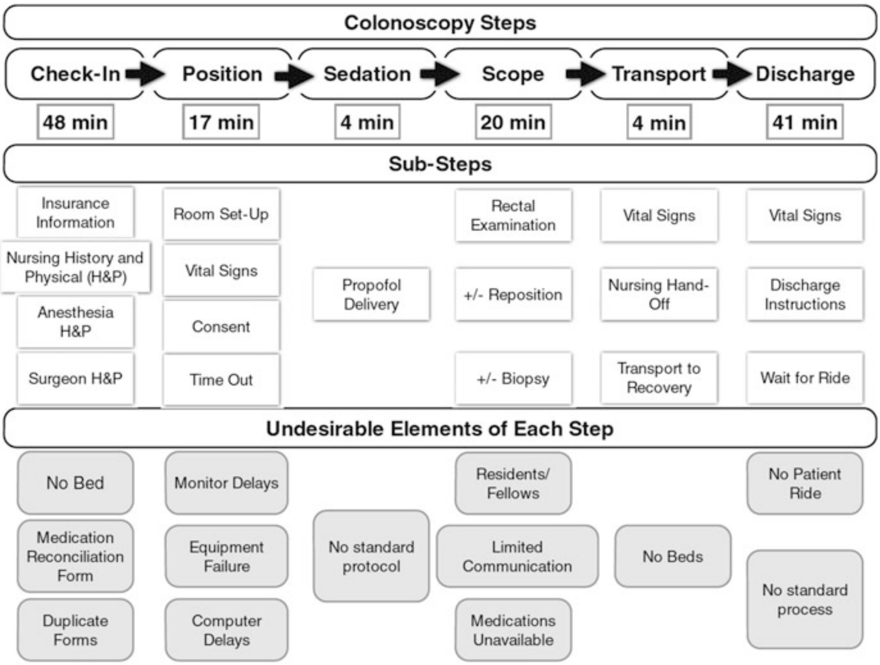

Fig. 3 Value stream map for colonoscopy (Damle et al. 2016)

and implementation of a variety of healthcare processes (Malcolm and Milstein 2016).

Lean is well suited for application to clinical laboratory settings (Riebling and Tria 2005; Elder 2008; Hurley et al. 2008; Condel et al. 2004). These environments deal with numerical precision and quality control in laboratory testing and measurement activities. It is also of a highly repetitive nature. Thus, mapping the value stream for areas such as laboratories appears readily amenable.

Another clinical arena similar to the laboratory is the Radiology Department. Radiology is a patient care area that employs repetitive steps in a complex system where many opportunities exist for employing lean approach. Process items from appointment scheduling to the final interpretation allow one to reduce clinical and technical errors and mistakes, diminish patient and report waiting times, improve patient outcomes through faster and more accurate reporting, increase the productivity of staff, improve customer (physician/patient) and employee satisfaction, and finally, decrease costs (Seltzer et al. 1997; Kruskal et al. 2012).

Along with all these efforts to create a continuous process flow in healthcare delivery services, IoT can be utilized as a promising platform to smoothly run the processes by reducing traditional hospital visits and waiting lines (Bhatt and Bhatt 2017) as well as reduced inventory and medical errors. The collaboration between Big Data and IoT on managing patient's individual electronic health records (EHR) and overall systematic data in healthcare has a potential for building a continuous process as well. This collaboration may even contribute to providing diagnosis and treatment for patients (Jeong et al. 2016).

Principle 3: Use pull systems to avoid overproduction

In lean, customers place their orders only when they need it. In other words, customers *pull* the final product from the production lines. Pull systems include several important essential requirements such as lowering inventory level, single-piece flow, and Kanban. Toyota Production System (TPS) specifically emphasizes the importance of inventory reduction (Monden 1998). Liker (2004: 99) points out that "inventory enables the bad habit of not having to confront problems." Liker (2004: 105) also addresses that "Toyota Way is not about managing inventory; it is about eliminating it."

As the purest form of pull (Liker 2004), single-piece flow is one of the main drivers in lean. According to Liker (2004: 99), when operations are linked to one-piece flow, the entire process shows a lower performance if any one piece of equipment fails. Due to the nature of healthcare services, each patient/process is considered an individual entity to be taken care of as planned. Patient, individually, is examined by healthcare providers and the treatment is determined on the basis of the patient's health conditions. This reality addresses the compatibility of one-piece flow naturally in healthcare due to the fact that the ideal batch size in lean is one. For instance, if a biomedical device in a diagnostic/treatment process stops unexpectedly, the entire service delivery process stops and delays until it gets fixed. In this example, very differently from the manufacturing setting, the probability of putting the patient's life at risk is another negative outcome that should be taken into consideration by the decision-makers of the process.

There are particular studies in the literature pointing out that lean requirements are not compatible with some certain industries such as healthcare. For example, Christopher and Towill (2001, 2002) state that lean cannot be implemented in industries where demand is highly variable and customization is high. However, due to the fact that each patient has unique symptoms, health conditions, and treatment ways, one-piece flow rule is compatible with the healthcare industry. Similar to production lines that are based on mix-model production systems, admitting each patient individually is a way of implementing one-piece flow rule in healthcare processes. Based on the physician orders, the rest of the diagnostic and treatment processes are shaped as a way of one-piece flow combined with mix-model service delivery. Additionally, healthcare services do not start operating before a patient demand appears; which means that healthcare delivery systems naturally run based on "pull."

The philosophy of just-in-time (JIT) requires the provision of what is needed when they are needed at the right amount, at the right place, and at the right time. Starting from this motto, JIT concept and Kanban can be easily implemented in healthcare (c.f. Rust 2013). For instance, medical inventory should not be stored on the shelves, instead, in lean, the inventory is required to be provided by the supplier when they are needed (c.f. Toussaint and Berry 2013; Hintzen et al. 2009). Similarly, patient transportations between departments should be scheduled in such a way that none of the service providers or patients are required to wait. From another point of view, patients are expected to show up at the designated places at the right time. For example, reducing turnover time in ORs relatively depends on the delay of patients taken to the OR.

From a different perspective, researchers have been examining input into the healthcare system (patient load) more critically since recognizing the input into certain systems may not be appropriate. The US Congressional Budget Office estimates that 30% of healthcare provided is unnecessary, defined as services that do not improve the patient's health. With that in mind, some have challenged specialty societies to develop a list of relatively expensive procedures that do not provide meaningful benefit to at least some categories of patients for whom they are commonly used (Brody 2010). Among others, examination of true need for intervention for health problems such as breast cancer (Pezzin et al. 2016), laboratory orders (Johnson et al. 2016), psychiatric admissions (Shaffer et al. 2015), and prostate cancer screening (Wilt and Dahm 2015) are being scrutinized in an effort to reduce needless input into the system.

Another attempt to reduce overproduction and decrease "pull" targets the consumer side in healthcare. Matching demand to appropriate resources is being attempted by some, with examples ranging from nursing home ratings (Werner et al. 2016) to crowdsourcing costs of care (Meisel et al. 2016). Others have attempted to reduce loading by identifying higher-risk individuals that "burden" healthcare systems with the inability to control the time and quantity of workload available in the system to address these individuals. One study at Cleveland Clinic calculated that 10% of their patients cost 60% of total expenditures (Lee et al. 2017). The authors concluded that higher cost patients are heterogeneous and most are not easily identified patients with frequent admissions. They also concluded that effective interventions to reduce costs by matching resources to workload would require a more multifaceted approach to this population that requires higher resources. However, behavioral changes may be more difficult to implement after obtaining evidence for leaner input and establishing recognition of high value (Vegas et al. 2015; Wilensky 2016). Wilensky (2016) has stated that "it is hard to ignore that there is little evidence that we've made much measurable progress in addressing these problems." Even in the popular press such as the New York Times, lamentations exist that metrics that attempt to alter practice behaviors (Wachter 2016). We are beginning to see more cautionary tales such as these as we attempt to impose more "quality"-related and leaner processes on the human aspect of care delivery.

From an individual clinical practice standpoint, pull reduction may be difficult to implement. However, with large-scale public policy initiatives, e.g., smoking cessation, motivating the populace to improve health habits, while slowly reducing interventions of low value, may be more prudent. Tobacco smoking cessation efforts, while requiring an "extra" expenditure of money, have been proven to reduce healthcare costs. In 2004, the WHO estimated that over 10 years (2006–2015), 13.8 million deaths could be averted by the implementation of smoking cessation interventions. Population-based intervention strategies could therefore substantially reduce mortality from chronic diseases while reducing patient loading into the healthcare systems. Extra evidence that load is reduced is that tobacco smoking is associated with higher hospital lengths of stay (Rezaei et al. 2016) and overall increased costs of care to an estimated total economic cost in the USA at more than $300 billion a year (Hall and Doran 2016).

Principle 4: Level out the workload (*heijunka*)

"Operationally, lean synchronizes supply with demand by leveling demand inside production processes and working with suppliers to reduce lead-times toward JIT supply delivery. This goal, called *heijunka* (load-leveling), is the foundation of the TPS and all lean manufacturing" (Rust 2013: 37). Aronsson et al. (2011) express that *heijunka* is linked with process redesign in lean. From this perspective, Christopher (2000) addresses that lean is the best way to follow when load-leveling is possible, demand is predictable, the requirement for variety is low, and volume is high (Christopher 2000). Healthcare industry may rely on "load-leveling" and "high volume" components of lean in order to improve overall performance. However, predictable demand and low variety requirement may not be applicable in all healthcare processes, particularly in trauma centers and ERs where demand is uncertain and unplanned. As stated by Rust (2013: 86), lean aims at stabilizing uneven demand. In addition to this, outpatient centers, ORs, or ambulatory care units run based on planned scheduling where demand is certain and apparent. Appointment-based planning systems may help implement load-leveling in healthcare in addition to the fact that all types of healthcare demands may not be met by planned systems. At that point, Liker (2004) points out that schedules in service operations are leveled by fitting customer demand into a standardized schedule and establishing standard times for delivering different types of service.

According to Naylor et al. (1999), lean aims to ensure level schedule in the manufacturing setting. In service setting, leveling schedule focuses on eliminating variation and uncertainty. In this manner, Rust (2013) links level schedule and high-capacity utilization as the main expectation in healthcare. *Heijunka* is suggested by Weber (2006) to smooth the service delivery pace in healthcare, while continuous flow and *takt* time are suggested by Liker (2004) to be applied in relatively high-volume and repetitive manufacturing and service operations. In this sense, some departments such as test laboratories and treatment and diagnostic procedures in outpatient and inpatient clinics are considered the best places where continuous flow and *takt* time may apply in the healthcare setting.

Principle 5: Build a culture of stopping to fix problems, to get quality right the first time

Solving problems at their source results in saving resources (Liker 2004). Along with this understanding, lean suggests stopping the lines in order to prevent defects and errors. Mistake-proofing and standardization are important components of this understanding. Monden (1998: 227) states that "there are two ways to stop the line when abnormalities occur: by relying on human judgment and by means on automatic devices." The first alternative has already been implemented in healthcare processes for many centuries. Since the beginning of the science of medicine, physicians have taken a leadership role in designing the care processes. "Don't harm and don't hurt the patient – *primum non nocere*" is the first motto taught at schools of medicine as a universal rule. The second alternative has been implemented in healthcare along with the integration of various engineering disciplines in medicine. A great variety of engineering-based discoveries and inventions have changed and improved the diagnostic and treatment processes in healthcare. In a general perspective, because of these two distinctive points, healthcare processes have already accommodated the essentials of the culture of stopping to fix the problems. Additionally, in today's healthcare industry, IoT-related systems, devices, and applications, such as medical sensor devices, aim to improve medical decisions made by care providers and minimize and prevent potential abnormalities. As more IoT devices are placed in healthcare processes, the importance of health data collected through these devices cannot be ignored in the future (Anumala et al. 2015), especially in order to determine where, when, and in what condition to stop the healthcare.

Stopping the processes is named as *jidoka* or *autonomation* in lean, as one of the two pillars of lean. Grout and Toussaint (2010) ask this question for healthcare professionals: "When in doubt, is the best action no action at all?" This question takes the conversation to the point where it is more acceptable to stop services rather than let them harm relevant parties in the process. In the manufacturing setting, *jidoka* empowers employees to stop the production lines. In a similar approach, *jidoka*, which means "react at first defect," is naturally used in healthcare processes. For example, if any abnormalities occur in a blood transfusion, the procedure is immediately halted. In any medical procedures, if the vital signs of the patient get worse, the procedure is stopped. Medical devices and biomedical equipment, giving colorful or sound signs that are similar to *andon* in the manufacturing setting, are utilized in these procedures. Burgess (2012) and Machado and Leitner (2010) emphasize that patient safety alert systems are utilized for care providers in case a potential error is about to occur. Furman (2005) perceives each staff at hospitals as an inspector who can stop the line to improve patient safety. IoT-related systems may also help healthcare providers improve patient safety and identify potential areas where the care delivery process needs to be stopped. Grout and Toussaint (2010) reported that Seattle's Virginia Mason Medical Center had 8000 stoppages based on this safety inspector concept.

As a crucial component of *jidoka*, mistake-proofing, namely, *poka-yoke*, is integrated into lean efforts. *Poka-yoke* means avoidance of inadvertent errors (Shingo 1986). In a comprehensive approach, Grout (2007) describes mistake-proofing as "the use of process or design features to prevent the creation of non-conformances." From this perspective, Grout and Toussaint (2010) address that even basic warning labels are considered mistake-proofing tool since these labels are capable of avoiding mistakes and nonconformities. The main idea in *poka-yoke* is to make it impossible for operators and employees to make an error. Implementing poka-yoke in healthcare may also help decrease malpractice lawsuits (Grout et al. 2013). *Poka-yoke* devices are assembled in the processes and equipment and operators do not even recognize that such devices are active to prevent them make an error. *Poka-yoke* including two segments such as (1) detecting the defect and (2) correcting the error is likely to reduce adverse events and medical errors in the healthcare setting. Considering that deaths caused by preventable medical errors in US hospitals have been a rising issue in patient safety (Kumar and Steinebach 2008; McLaughlin and Olson 2012), *poka-yoke* should be utilized as a remedy in healthcare. As an example of effective *poka-yoke* ways in these two segments, Grout and Toussaint (2010) point out how easier to detect surgical sponges left in patients than discovering them after surgery finalized. Standardized double checkpoints on sponges used in the surgery processes should be perceived as an example of procedural *poka-yoke* approach. Similarly, the single-use plastic locks used in blood transfusion, automatic wheelchair brakes, marked floors, wristbands, and central line kits are given as the other examples of *poka-yoke* in healthcare. In a more primitive approach, at the beginning of the care process, patients are involved in the process by orally confirmed their names and the type of medical intervention in the ORs to prevent mixing-up patients. At that point, *timeouts*, *sign-your-site*, and *read-back* are other mistake-proofing examples systematically embedded in healthcare processes (Grout and Toussaint 2010). As given in Grout and Toussaint's (2010) study, ThedaCare showed a high performance on patient safety and healthcare quality especially by focusing on *jidoka* and *poka-yoke* in the USA. According to Manos et al. (2006: 27), "the key is to set up the system so there is no chance for error." They also give bar-coded or computerized physician order entry systems as examples for mistake-proofing practices. Manos et al. (2006) also give pulse oximeters as another example of *autonomation*. When pulse oximeters become loose or disconnected from the patient, the reading sets off an alarm for healthcare providers to intervene the condition. As seen in those examples, the culture of stopping is already an integrated part of the healthcare systems.

The potential impact of IoT should be taken into consideration in this principle. As stated by Anumala et al. (2015), IoT hubs connecting health devices and smart appliances may generate new data for caregivers and decision-makers. Connecting patients with doctors, nurses, and other direct and indirect caregivers via devices and tools embedded in IoT may improve the quality of patient monitoring processes and decrease the likelihood of adverse events, errors, and failures.

Principle 6: Standardized tasks are the foundation for continuous improvement and employee empowerment
Standardization was developed and utilized particularly in manufacturing work settings. Standardized work is likely to improve quality since employees will be trained to follow standardized work in lean (Manos et al. 2006). Gomez et al. (2010: 85) stated that "standard work can be thought of as the best combination of activities that will limit activities that don't add value" with the goal of highest quality healthcare. Similarly, standardization is an indispensable component of healthcare. Kumar and Steinebach (2008) and Kohn et al. (2000) report that experts suggest "standardization" as the remedy to reducing medical errors since standardization is likely to reduce the variation which increases complexity, risk, and error. The error rate in the US healthcare system is estimated approximately at sigma level four (Kendall 2003), which turns into 6210 medical errors per million tasks. Lowe et al. (2012) state that standardized work allows doctors and nurses to perform at their licensure level more often because of effectively running processes. As reported by McLaughlin and Olson (2012), Park Nicollet Healthcare System in Minnesota implemented lean tools to help decrease the number and impact of the issues with the delivery of the anticoagulants, focusing on international normalized ratio time (INR) in the desired range. They achieved their goals by *standardized* policies and dosing models related to the administration of the medicine. As the main outcomes of lean, the organization was able to reduce the admission rate from 15.9% to 11.2% and cost from $1300 to $442 patient/year.

Even if some processes have to be patient-centric and can be changeable, the majority of the process flows are standardized. For example, standardized color-coded triage systems help physicians prioritize the patients in ERs. Other examples are standardized patient transfer procedures helping other care providers to figure out what to do in other departments and standardized electroconvulsive therapy (ECT). Jonsson and Randefelt's (2013) study focuses on how these standardized procedures eliminate waste in healthcare. In a similar vein, standardized care paths, treatment protocols, and worksheets are also integrated into healthcare and administrative processes. With regard to standardized care paths, ERAS (Enhanced Recovery After Surgery) can be given as an advanced example of standardization in healthcare. Particularly, standardized worksheets are developed especially for employees who perform in repetitive processes such as in-room patient preparation and patient discharge processes. Similarly, ORs, X-ray, MRI, or CT laboratories operate based on standardized procedures which result in reduced potential wastes. Gomez et al.'s (2010) study is an exemplar for showing the effectiveness of standardized work instruction sheets. Grout and Toussaint (2010) mention the consequences of the violence of hand-washing protocols as a root cause of stopping operations in ORs. The benefit of implementing standardization in healthcare is to easily detect deviations and have a chance to correct them (Jonsson and Randefelt 2013). Furthermore, IoT-oriented standardization has a huge potential to analyze the root causes of potential abnormalities in healthcare processes.

Spear and Bowen (1999) addressed that establishing process stability through standardization is utilized as a way to create a workforce capable of identifying problems and solutions. Even though "standardization" in lean is considered a vital base, variability and uncertainty associated with treatment and patients' health conditions result in problematic (doubtful) areas in healthcare. According to Rust (2013: 17), "the growing interdependence of healthcare delivery, coupled with pressure to reduce costs and serve greater numbers of patients, makes these delivery chains increasingly difficult to manage and coordinate." Rust (2013) also emphasizes that new service management strategies should be implemented in healthcare to manage changes, variability, and adverse effects of variability in patient demand. In addition, preventable medical errors resulting in 98,000 deaths each year were correlated with the lack of standardization and increasing variability in the healthcare industry (Kohn et al. 2000; McLaughlin and Olson 2012). In this manner, standardized care is more likely to contribute to patient safety as well as improved lean outcomes (Gomez et al. 2010).

Rust (2013) calls attention to the point where increasing demand variability causes revenue losses, increasing cost and stress on employees in the healthcare industry. Additionally, high complexity and uncertainty are seen two obstacles to implementing standardization and lean in healthcare (Rust 2013). That high complexity increases risks and makes the processes and healthcare providers harder to manage (Rust 2013).

Principle 7: Use visual control so no problems are hidden

Problems in the workplace must be visible to every employee (Monden 1998). In implementing *autonomation*, various visual controls, such as mistake-proofing tools, digital display panels, *kanban* cards, *andon*, call lights, and lines, monitor the flow of the production (Monden 1998; Liker 2004; Manos et al. 2006). Fillingham (2007) states that visual management helps determine whether the process is operated correctly and if problems or errors occur.

Even if it is not directly recognized, visual control approach takes place in a great variety of services in healthcare processes. There are certain departments and processes in which the concept of visual control is naturally implemented to help decision-makers, particularly clinically, in the healthcare industry. For example, visual timetables or schedules used in radiology (Gomez et al. 2010), labels and signs used in ORs, ERs, and clinics, patient monitors used to observe patient's vital signs, etc. As another visual control tool, *kanban* is a card usually placed in production lines to show the type and quantity of units needed in certain production areas (Monden 1998). Kanban system is also identified as "an information system that harmoniously controls the production of the necessary products in the necessary quantities at the necessary time in every process of a factory" (Monden 1998: 15). Rust (2013: 7) expresses that "demand variability may be the most pressing problem facing healthcare delivery today." Unplanned walk-in patients and visits and unpredictable healthcare demand should be considered in lean while focusing on how to manage Kanban systems. Daily-basis supply order systems in JIT have been implemented in some healthcare organizations. For example, Ballé and Régnier (2007) express that daily delivery in healthcare solves the space problems in inventory since it may result in less stock on hand. However, government-driven healthcare systems rather prefer to order for a period of time instead of putting orders on a daily basis. The main benefit of JIT for healthcare organizations is to save storage space and surface the problems hidden in excessive inventory systems. Manos et al. (2006) point out that inventory and supplies are the major costs in healthcare.

As a crucial component, visual control in manufacturing is basically based on 5S. Machado and Leitner (2010: 387) describe 5S as "a place for everything and everything in its place." 5S refers to "organize, set in order, cleanliness, standardize, and discipline." Ikuma and Nahmens (2014) identify 5S as a systematic approach to transfer a company's culture. The main idea behind 5S is to increase effectiveness and efficiency by eliminating unorganized and dirty workplaces. This idea complies with the healthcare processes since the work environment in healthcare cannot tolerate disorganized and contaminated conditions. Machado and Leitner (2010) express that frequently used items should be placed closer to the workplace and easier to attain than rarely used items. In one case, Laing and Baumgartner (2005) reported that an endoscopy unit saved 17 minutes in cycle time by implementing 5S methodology in a community hospital. Gomez et al. (2010) performed first-step 5S efforts during the weekends by offering overtime to healthcare providers. Additionally, Ikuma and Nahmens (2014) showed how 5S could be integrated into safety-oriented efforts in acute care facilities. Kim et al. (2009) showed that nurses could identify quality and safety issues by using 5S supply carts. Esain et al. (2008) reported that the National Health Service (UK) benefited from 5S projects.

Based on the nature of healthcare processes, labeling, coding, sorting, and classification of the drugs, medicines, material, medical equipment, tool and supplies, spaces and even patients have been used for a long time, as identified in the first two components of 5S. The requirements of cleanliness component of 5S are also in the same line with the cleanliness, sterilization, and medical hygiene requirements. Furthermore, the sterilization procedures in healthcare may be beyond the regular cleanliness expectations in lean.

Principle 8: Use only reliable, thoroughly tested technology that serves your people and processes
In lean, new technology is implemented after approved by all relevant parties. The main question in this technology vetting process is whether new technology is capable of improving and adding value to the existing system. While analyzing and testing new alternative technology very slowly and safely, implementing new technology is done very quickly. Liker (2004) states that:

> Toyota has tended to lag behind its competitors in acquiring all types of new technology . . . The Toyota Way is to move slowly because more than one technology has failed to meet their "acid" test of supporting people, process, and values and has been yanked in favor of simpler, manual systems. Toyota is still following this policy in the age of digital technology . . . Throughout this analysis and planning, Toyota will broadly involve all key stakeholders in a consensus-building process.

The requirements of this principle have been neglected by lean practitioners in various industries. It may be seen as one of the root causes of failing lean implementation. Even if hospitals in the USA implement the most advanced technology in the processes, the association between the technological investment and patient outcomes is seen weak and not significant by the researchers (c.f. Himmelstein et al. 2010). Additionally, technology is considered one of the primary contributors of rising healthcare costs (Health Care Costs Report 2007) even if the expected impact on overall performance is lower than the actual one (Husby 2012). By looking into this concern, healthcare organizations should (1) analyze, (2) test, and (3) approve the potential risks, benefits, opportunities, and values of improving technology, before transferring it (Liker 2004). This is compatible with the cultural change integrated into lean transformation in healthcare. As stated by Liker (2004), the entire technology transformation process should be analyzed to see if it conflicts with the organization's philosophies and operating principles. Considering that today's healthcare industry talks about IoT, Big Data analytics, medical sensor devices, telemedicine, and e-health, technology adaptation and export requires a huge amount of time and effort devoted to lean implementation in healthcare systems. As a highly regulated industry, any potential or current change in technology implemented in healthcare processes should be comprehensively reviewed.

2.3 People: Respect and Development

As addressed by several parties (c.f. Zidel 2006; Liker 2004; Womack and Jones 1996), a lean transformation requires an organization-wide paradigm shift. That transformation process can be constructed on the following three principles given under *People* principle. Emiliani (2006: 169) states that the "respect for people" has long been unrecognized, ignored, or misunderstood by most senior managers outside Toyota and its affiliated suppliers. Even though the majority of the publications focus on how to implement lean in healthcare, limited studies worked on the *soft* part of lean. From this point of view, Husby (2012) articulated that *people*, process, and technology are the three crucial areas of focus for US healthcare organizations.

Principle 9: Growing leaders who thoroughly understand the work, living the philosophy, and teaching it to others
Human assets are one of the crucial resources in lean success. Toyota leaders are raised up and promoted in the hierarchy of the firm in lifelong employment to become effective leaders. Liker (2004) emphasizes that in Toyota's history, key leaders have been found within the company. Toyota expects leaders in all level to introduce, educate, and teach their subordinates the Toyota culture (Liker 2004; Liker and Convis 2011) and encourage them for lean transformation (Atkinson 2004; Boyer and Sovilla 2003). Culturally, these traditions are not shared by Western business organizations. However, healthcare organizations should implement such a strategy to raise their own leaders and train them about lean philosophy. At that point, transformational leadership (Bass 1999) and servant leadership (Greenleaf and Spears 2002) are linked with lean leaders.

McLaughlin and Olson (2012: 4) emphasize that "excellence in healthcare derives from three major areas of expertise: clinical care, *leadership*, and operations." Essentially, top management support is considered a crucial success factor in lean implementation regardless of the type of the industry (Boyer and Sovilla 2003; Womack and Jones 1996). The role of leadership is accepted as an essential factor for improved quality and safety in healthcare (Sollecito and Johnson 2013). For example, Gomez et al. (2010) address that strong leadership support in their study helped in lean transformation. Liker and Convis (2011) and Husby (2012) perceive leadership function as a critical success factor at hospitals for the long-term success in lean. Fine et al. (2009) reported that when the top leaders of the hospital were fully engaged in lean initiatives, the effort spread across the organization more quickly. Within this understanding, leaders in healthcare organizations should be raised up and trained in accordance with lean in order to increase the likelihood of lean achievement.

Principle 10: Develop exceptional people and teams who follow your company's philosophy
"Toyota invests in people, in return, it gets committed associated who show up to work every day on time and are continually improving their operations" (Liker 2004: 198). While Zidel (2006) states that lean organizations value their employees and encourage them to involve in organizational initiatives, the healthcare industry has experienced many challenges such as decreasing reimbursement, staffing shortages, and increasing costs over the last decades (Husby 2012). All these challenges limit investments in staff and teams who work on process improvement and problem-solving. Instead, by looking from a lean perspective, it is seen that healthcare organizations invest in employees' and teams' training and education to increase the likelihood of lean achievement in the long run.

Manos et al. (2006) point out the importance of relying on the employees' knowledge and skills especially in problem-solving processes. According to Manos et al. (2006: 25), “the people closest to the work know it best. They are the process experts and they just have to be trained in problem-solving and lean techniques. One of the advantages of the lean technique is that the staff involved directly in the process are the ones who work to improve it.” De Souza (2009) points out “staff empowerment” as one of the key aspects making lean more acceptable in healthcare in addition to gradual and continuous improvement. In the same line, the respondents in Jonsson and Randefelt’s (2013: 31) study state that “it is important that all the employees feel as a part of the organization and all employees are encouraged to suggest improvements.”

Liker (2004) also emphasizes on the necessity of focusing on the interaction of teams and employees and perceiving teams as the focal point for problem-solving. The teams in TPS are located at the top of the hierarchy. Liker (2004: 185) states that:

> All systems are there to support the team doing value-added work. The teams coordinate the work, motive, and learn from each other. Teams suggest innovative ideas, even control through peer pressure . . . Excellent individual performers are required to make up teams that excel.

In the healthcare industry, patient-centered multispecialty teams including physicians, nurses, social workers, etc. manage the entire patient care process, clinically and administratively (Sollecito and Johnson 2013). Very similar to TPS, since patient care is managed and given within naturally built teams, the teams should be put at the highest hierarchical level and the rest of the organization should be managed to maximize the patient care team performance.

Principle 11: Respect your extended network of partners and suppliers by challenging them and helping them improve

As expressed by Liker (2004), TPS establishes high standards and expect all their partners to raise those standards. According to Deming (1986), the fewer the number of suppliers, the higher the organizational performance. Deming (1986) and Bicheno (1999) also recommend working with suppliers very closely in a long-term orientation and supporting them to improve the quality of their outcomes. Similarly, establishing long-lasting collaboration between healthcare providers and reducing the number of suppliers are seen two important requirements in the healthcare industry (Aronsson et al. 2011). Depending on reliable lean suppliers and partners is likely to increase the success of lean implementation (MacDuffie and Helper 1997; Liker 2004; Womack and Jones 1996). MacDuffie and Helper (1997) state that:

> . . . customers are likely to demand that suppliers assume substantial responsibility during product development, accommodate customer requests for engineering changes in their product or manufacturing process; be highly reliable with respect to quality and delivery; and have the ability to respond quickly in case of problems. These requirements are difficult for a supplier to meet unless they have adopted lean production practices themselves. Thus a lean customer is likely to find it more productive to work with lean suppliers.

In the same vein, healthcare organizations are supplied by a great variety of organizations such as pharmaceutical companies, biomedical device producers, and R&D firms. As the leading industry in lean, the automobile industry has trained its partners and helped them become a lean supplier (MacDuffie and Helper 1997). However, the healthcare industry has not arrived at such a matured customer-partner relationship level yet. Aronsson et al. (2011) pointed out that the healthcare industry is in need of great system-wide changes in the supply management function. Instead, Husby (2012) points out that physicians are separated from lean efforts, which blocks the potential positive outcomes of lean efforts that might be managed by the physicians. It is obvious that the integration of physicians into lean from top to bottom, as the main director of patient care in one-piece flow, is more likely to increase the effectiveness of healthcare. Inspired by best practices, the healthcare industry with its partners should focus on how to implement lean principles to decrease *muda* in the industry.

2.4 Problem-Solving: Continuous Improvement

Principle 12: Go and see for yourself to thoroughly understand the situation (Genchi Genbutsu)

Processes and performance issues should be analyzed by the service providers, designers, and managers at firsthand to understand the root causes of high variability in healthcare. Performance-related issues should be monitored in the place where they occur, *gemba*, to figure out assignable and common causes resulting in variability (Kruskal et al. 2012). Seasonal or random variability add complexity to healthcare processes (Husby 2012). In order to decrease response time to problems and increase the probability of solving the problems, problem solvers in healthcare processes should be in *gemba* (c.f. Toussaint and Berry 2013; Fine et al. 2009).

Principle 13: Make decisions slowly by consensus, thoroughly considering all options, implement rapidly

In lean, it is expected to run decision-making processes collaboratively based on data throughout the hierarchical structure (Liker 2004). Rosmulder (2011) reported that lean efforts would be useless if there was no system-wide participation in lean projects. At the heart of healthcare, routine diagnostic and treatment processes are compatible with this principle due to the fact that diagnostic processes take relatively longer to consider all potential possibilities. Compared to diagnostic processes, treatment ways are determined by physicians based on protocols and standardized procedures. In addition to explicit knowledge, Husby (2012) mentions the importance of using tacit knowledge developed in healthcare processes to improve patient care-related outcomes. In this manner, tacit knowledge, which is seen as a barrier to transfer evidence-based medical knowledge into actual care (Husby 2012), produced with the help of PDCA may be used as a base for decision-making processes in lean practices in healthcare. Parallel to advancements seen in data management, particular topics such as Big Data and IoT have emerged as the promising areas for healthcare organizations. Considering the excessive need for better and timely decisions in the healthcare industry, all these advanced technologies may help decision-makers function in this principle more effectively.

Principle 14: Become a learning organization through relentless reflection (hansei) & Continuous Improvement (Kaizen)
Ballé and Régnier (2007: 33) point out that "lean is a learning method more than anything else." Based on knowledge generated in lean, healthcare organizations become capable of utilizing the current knowledge for providing better care and making better decisions. A continuous learning process is built based on lean pillars such as continuous improvement, standardization, and stability. Taichi Ohno (1988) states that without standards, there is no *kaizen*. At that point, using both explicit and tacit knowledge in lean effort takes the healthcare organizations to a higher performance level, especially in terms of sustaining lean efforts and becoming a learning organization. The learning environment should be created not only for a process but also for the entire healthcare delivery system.

3 The Limitations of the Study

The primary limitation of our research and the resulting manuscript is that, although much has been discussed and implemented in the lean process as it relates to manufacturing and service processes, clinical application of the lean method into healthcare processes is relatively scarce. Based on our review of published examples of lean in healthcare, the most consistent feature was the difficulty encountered in implementing the intended training and improvement projects. Most studies demonstrated multiple barriers to progress inherent in the very systems and culture they were attempting to improve. There are clearly important questions here that need to be addressed. The organizational structure of healthcare systems appears to most outside observers as highly complex with multiple lines of accountability. It is important to understand why this structure has evolved and persisted, despite the obvious disadvantages. The assumption that a clearer and simpler structure with stronger accountability would be more effective and safer for patients may need to be tested empirically at some stage, but this would clearly involve a very large-scale experiment (essentially a whole trust, but with implications that would certainly attract comment and concern from national professional bodies, unions, and others).

The business literature demonstrates that dealing with the theory of organizational change and an important component of any investigation of organizational barriers should be an attempt to comprehend these through this perspective. We recommend observational and analytical studies of the relationships between culture, organizational structure, and resistance to change in healthcare organizations, in collaboration with experts in change management. An attempt to create a large and practical trial of lean interventions will need to be designed using an approach framed in an appropriately adapted theory of organizational change.

If we accept that major changes to organizational structures are likely to be difficult at best to achieve, future qualitative research into the attitudes to safety interventions and system improvement expressed by different staff groups will be useful in understanding how these might be changed or circumvented when they appear unhelpful. Research such as this may require the use of sophisticated theory-based questionnaires to differentiate between attitudes and motivations, which are often engendered by the expectations of the organization and professional peer groups. These are deep, and perhaps, subconscious drivers which show themselves in decision-making choices rather than public statements made for political purposes. Using previous research on organizational culture and organizational change theory, it may be possible to create a predictive model that will help to identify how a given organization will react to attempts at systems change and test this against the outcome of real-life improvement projects.

4 Conclusion

In this chapter, we have discussed the lean process as one management approach that we can use to examine operational aspects. We also have discussed the social and technical dynamics associated with these improvement systems. We have also focused on how one can start to apply these insights to healthcare.

In lean implementation, one must take into account the variety of issues surrounding the application of lean thinking to healthcare. One difficulty regards the social and technical issues that occur when implementing lean thinking. Research on sociotechnical dynamics in lean organizations, especially in healthcare, is virtually absent.

Operational aspects of lean thinking and their relationship to performance have been looked at thoroughly, but application to healthcare has been limited. The same goes for cumulative capabilities, where research in and out of healthcare is scarce. More attention is needed to verify these key propositions of lean thinking in healthcare. Even if these problems are addressed and lean delivers on its promises, the challenges to increasing the role of lean thinking are very future-promising. The value produced is more or less ephemeral, difficult to specify, and unclearly priced into the equation.

A lean transformation requires an organization-wide paradigm shift. It requires no less than the redesign of the healthcare system as we now see it. Perseverance, high-quality leadership, dedicated professionals, high quality and timely data management and knowledge creation, and patience are surely needed. Doubt and the resulting resistance will be high. Organizations may take a long period of time before embarking on such a journey. Worse, they may superficially implement lean thinking, adding to existing resistance; thus, making it more difficult to improve healthcare in the long term.

We believe lean thinking has the potential to improve healthcare delivery. At the same time, there are methodological and practical considerations that need to be taken into account. Otherwise, lean implementation will be superficial and fail, adding to existing resistance and making it more difficult to improve healthcare in the long term.

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