

Preface

At a very fundamental level quality of care is about meeting the physical, psychological, and social expectations of patients who search for care. The American Institute of Medicine (IOM) refers to quality of care as “the degree to which health services for individuals and populations increase the likelihood of desired health outcome consistent with current professional knowledge” (Kumpersmith 2003). The term “health service for the individuals” in the definition is a reference to service quality as well as the link between service quality and patients, i.e. customers. This link is further strengthened in this definition with the application of professional knowledge. In fact the link between quality and customers has been established in the healthcare industry as early as 1910. In 1910, the American surgeon, Ernest Codman, developed the concept of “end result idea” in hospitals. The concept requires the following: “Every hospital should follow every patient it treats long enough to determine whether the treatment has been successful, and then to inquire ‘if not, why not’ with a view to preventing similar failure in the future” (NCBI 2005). While initially this may not have been embraced readily (Who_Named_It 2005), today, Dr. Codman is remembered as a guru for quality of care and The Ernest A. Codman Award was created in 1996 to showcase the effective use of performance measures and to encourage the quality of care. Ironically, in this same year, the Advisory Commission on Consumer Protection and Quality in the Health Care Industry was established. The Commission notes the following quality problems in hospitals (Advisory_Commission 1998):

1. *Avoidable error*: the report points out that too many Americans are injured and died prematurely as a result of avoidable errors. The report claims that “from 1983 to 1993 alone, deaths due to medical errors rose more than twofold, with 7,391 deaths attributed to medication errors in 1993 alone”.
2. *Underutilization of services*: the report claims that millions of people do not receive necessary care. It estimated that about 18,000 people die each year from heart attacks because they did not receive effective interventions.

3. *Overuse of services*: the claim was that millions of Americans receive healthcare services that are unnecessary.
4. *Variation in services*: there is a continuing pattern of variation in healthcare services, including regional variations and small-area variations.

More recently, in 2000, IOM released its landmark report, entitled “To Err is Human: Building a Safer Health System” (Kohn et al. 2000). This report concentrates on errors within the American healthcare systems and concludes that majority of medical errors are caused by faulty systems, processes, and conditions that lead people to make mistakes or fail to prevent them. Moreover, the report stresses that “when an error occurs, blaming an individual does little to make the system safer and prevent someone else from committing the same error (ibid)”.

About 15 months after releasing its landmark report on medical errors, the IOM released its second report, titled “Crossing the Quality Chasm: A New Health System for the 21st Century” (IOM 2001). This second report emphasizes a gap or “chasm” between the quality of care for the existing health system and the expected quality of health that should be delivered and set forth a vision for transforming quality of the health system. In consistency with the findings of the Advisory Commission (Advisory_Commission 1998), the IOM report calls for improvements in six dimensions of healthcare performance: safety, effectiveness, patient-centeredness, timeliness, efficiency, and equity (Table 1). It asserts that “those improvements cannot be achieved within the constraints of the existing system of care” (Berwick 2002). In response to this challenge, the Institute of Medicine (IOM) and the National Academy of Engineering (NAE), released a third report, titled “Building a Better Delivery System: A New Engineering/Health Care Partnership” (Reid et al. 2005). In an attempt “to bridge the knowledge/awareness divide separating healthcare professionals from their potential partners in systems engineering and related disciplines”, the NAE/IOM study identifies system engineering applications that could contribute significantly to improvements in healthcare delivery and emphasizes that tools transforming the quality and productivity performance of other large-scale complex systems could also be used to improve healthcare delivery. The report highlights the role of information and recognizes the importance of human factors techniques and the significance of adapting Toyota Production System (TPS) concepts to healthcare performance. The TPS is a collection of ideas, techniques, and procedures developed by Toyota mainly after World War II. The focus of TPS is to produce cars that satisfy customers and fits their requirements. The principles are producing cars with best quality at the lowest costs and with shortest lead time through systematic elimination of waste and improving performance.

Given this growing importance placed on quality and value creation for healthcare delivery, coupled with the plethora of technology solutions now being developed that facilitate (or at least claim to facilitate) better healthcare delivery, we believed it was timely to examine the issue of lean thinking for healthcare together

Table 1 Six quality aims for the twenty-first-century healthcare system proposed by IOM (2001)

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- *Safe*—avoiding injuries to patients from the care that is intended to help them
 - *Effective*—providing services based on scientific knowledge to all who could benefit and refraining from providing services to those not likely to benefit (avoiding underuse and overuse, respectively)
 - *Patient-centred*—providing care that is respectful of and responsive to individual patient preferences, needs, and values and ensuring that patient values guide all clinical decisions
 - *Timely*—reducing waits and sometimes harmful delays for both those who receive and those who give care
 - *Efficient*—avoiding waste, including waste of equipment, supplies, ideas, and energy
 - *Equitable*—providing care that does not vary in quality because of personal characteristics such as gender, ethnicity, geographic location, and socioeconomic status
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Source: IOM (2001), pp. 5–6

with related and complementary concepts such as six sigma, kaizen, and constraint management. Hence, together with our colleagues around the world, we set about creating this magnum opus that serves to explore and present in one volume critical issues relating to lean thinking and its application in a variety of healthcare contexts in order to facilitate and enable superior healthcare delivery to ensue.

Introduction to Lean Thinking

During 1980s, Professors Womack and Jones of Massachusetts Institute of Technology (MIT) conducted a 5-year project for studying TPS and publish their book, entitled “The Machines that Changed the World” in 1990 and they coined the term “lean production” as synonymous to the TPS (Womack et al. 1990). The term “lean” is used because the lean production uses less of everything compared to other production systems. Since its introduction, the concept of lean production has changed considerably (Joosten et al. 2009). It is diffused from car industry to other manufacturing industry and then to service industry (Hines et al. 2004). Originally, the application of lean at Toyota was a process-oriented concept. Currently, lean extends beyond the original Toyota operational shop floor concept to include “respect-for-human system” aspects besides the technical aspects of the system under study (Joosten et al. 2009; Sugimori et al. 1977). In other words, application of lean requires looking to the system as “sociotechnical” system in which human factor engineering and technology plays the central role. Womack and Jones (1996b, 2003) enhance further the “sociotechnical” aspect of lean production through introducing five principles within which the customer value and waste reduction are the cores of the lean system (Joosten et al. 2009; Womack and Jones 2003). Womack and Jones coin their principles with the term “lean thinking” with emphasize to applicability of lean thinking to service industry including healthcare services. Table 2 describes the five principles of lean thinking.

By definition, customer value is a reference to activities which from the viewpoint of the customer add value and the customer is ready to pay for (Womack and Jones 1996a). Accordingly, activities of a process or system can be divided into two

Table 2 The five principles of lean thinking (adapted from Inozu et al. 2012; Black 1984)

No.	Principle	Meaning
1	Value	Value is any activity, step, or event that improves the customer experience (Powell et al. 2009). This principle requires specifying the values the customer actually wants in order to provide them
2	Value stream	Value stream—streaming a process means mapping (dividing) activities within the process. It may require dividing each activity to its sub-activities or steps and so on. Value stream means that the activities of a process should provide value. This requires streaming the process into activities and then sub-activities/steps and identifying those steps that add no value from the customer perspective (i.e. waste) with the aim to eliminate them
3	Flow	The principle requires smoothing the flow of work, material, and information. It may require redesigning the process to create continual flow and eliminate bottlenecks
4	Pull	Align the supply of services or product with customer demand. Services or goods are only provided upstream when the customer downstream requests for them (Powell et al. 2009). It also means that all work, material, and information should be pulled to perform tasks when needed (Jones and Mitchell 2006)
5	Perfection	This principle requires continual improvement such that each improvement in the process creates a platform for the next one (Jones and Mitchell 2006)

main types of activities; value adding activities and non-value adding activities. Value adding activities contribute directly to the production of products or services while non-value adding activities do not make such contribution and, accordingly, can be considered as waste that should be considered for possible reduction or elimination. Waste is anything other than the minimum amount of equipment, effort, material, parts, space, and time, which are absolutely essential to add value to the product [or service] (Cho and Makise 1980; Russell and Taylor 1999). There are two kinds of non-value adding activities; activities add no value but are necessary such as transportation and those activities that can be avoided and can be considered as complete waste (Monden 1993). Lean thinking attempts to eliminate or reduce waste by eliminating unnecessary non-value adding activities and reducing as much as possible the necessary non-value adding activities. Literature specifies seven elements of waste (Ohno 1988). Table 3 provides description of the seven types of waste with examples from healthcare services (Table 3).

The aim of lean thinking is to provide what the customer wants, quickly, efficiently, and with little waste (Jones and Mitchell 2006; Young et al. 2004). It aims to substantially smooth the flow and drastically reduce waste and process variations (Womack et al. 1990; Taj and Berro 2006; Reichhart 2007). From the customer’s value perspective, waste is defined as the activity or activities that a customer would not want to pay for, and that do not add value to the product or service from the customer’s perspective (Shinohara 2006). Once waste has been identified in the current or existing state, a plan is formulated to eliminate this to attain a desired future

Table 3 The seven elements of waste (adapted from Inouzu et al. 2012; Black 1984)

Waste element	Lean principle	Quality aim	Comments/examples from healthcare services
1 Defect	Value stream	Safe, patient-centred	A defect occurs when the output was not as intended or does not fit with the requirements and specifications. It may require corrective action, or repeating the activity. Examples include medical assessment errors, adverse drug reaction, providing wrong drug, performing surgery on the wrong side, and readmission patient because of wrong discharge
2 Transportation	Flow/value stream	Timely, efficiency	This is a reference to the movement of material and equipment. It includes also the transportation of a patient from one place to another. Transportation may be necessary and cannot be avoided but can be considerably reduced using process re-engineering. For instance, having preoperative area adjacent to operating room reduces considerably the patient movement
3 Motion	Flow/value stream	Timely, efficiency	It refers to the movement of medical staff to obtain material or information. Electronic transferring the medical test results or x-ray images eliminate the staff movement to obtain the results or images. Motion includes extra effort and movement in performing action such as using arm and shoulder rather arranging work place for less effort movement (human factor engineering)
4 Waiting	Pull/value stream	Patient-centred, timely, efficiency	This includes any delay in performing an activity or waiting for an action to occur. Examples include waiting for general practitioner, for medical results, for trolley to move a patient, or for medical information
5 Inventory	Value, value stream, perfection	Efficiency	It refers to excess material stocks in a storage. For healthcare, it refers to long waiting lists for surgery, medical assessments, or special treatments
6 Over-processing	Value, value stream, perfection	Effectiveness	Unnecessary repetition of an action. Examples include unnecessary recounting instruments, requesting same information from a patient several times, and receiving additional information which is not required
7 Overproduction	Value, value stream, perfection	Effectiveness	Unnecessary reproduction of the same product/service: example, repeating unnecessary x-ray or medical test, have unnecessary extra beds in discharge room, and leaving lights and air conditioning switch on after leaving offices

state in as effective and efficient a manner as possible. Lean Thinking provides the following benefits (Jones and Mitchell 2006): improved quality and safety, improved delivery, improved throughput—the same resources with higher efficiency, and accelerating momentum—A stable working environment with clear, standardized procedures creates the foundations for constant improvement.

Lean thinking comprises a set of approaches and techniques utilized to efficiently reduce waste in a way that achieves the five principles of lean thinking. Some of these approaches are old and developed during the second and third decades of twenty-first century such as method study and work measurement (Barnes 1980) while other approaches are recently developed such as Just-in-time (Womack et al. 1990) and process reengineering (Hammer 1990). The list of approaches and techniques is growing with the time. The main question that first needs to be answered is which technique(s) is (are) most suitable to achieve the aim of lean thinking for specific situation under study. However, lean thinking differs from other traditional approaches in that:

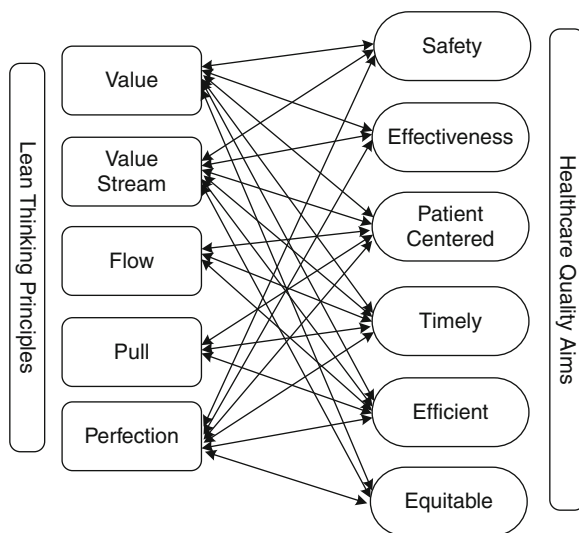
1. It looks to the entire process rather than specific activity of it. Improving an activity without addressing the whole process may not improve efficiency at all (Jones and Mitchell 2006).
2. It aims to achieve the five principles of lean thinking.

In order to achieve lean principles, the commitment to create lean thinking culture should start at the very top management of the organization (Miller 2005), keeping in mind that Lean “has to be locally led and be part of the organisational strategy” (Jones and Mitchell 2006). From operational side, there is a need to integrate more than one approach to achieve the requirements for lean thinking. The set of approaches may differ from one process to another. In addition, many approaches may require adaptation in order to be integrated with other approaches.

Lean Thinking for Healthcare Services

The literature emphasizes the applicability of lean thinking to healthcare services (Balle and Regnier 2007; Jones and Mitchell 2006; Young et al. 2004). Although some healthcare professionals may argue that lean thinking is more suitable to manufacturing and does not translate well to healthcare services; Bowen and Youngdahl (1998) show how it does apply to healthcare by providing theory, case studies, and context for lean applications. Flinders Medical Centre, a medium-sized public sector teaching hospital in Adelaide, South Australia, has, for some time, been implementing lean strategies (King et al. 2006) and has been able to operate below its budgeted costs (Jones and Mitchell 2006). Lean thinking has also been advocated in the healthcare setting of the USA through the use of the Six Sigma methodology, which in many ways resembles lean production techniques (Dahlgard and Dahlgard 2006; Tolga Taner et al. 2007; Young et al. 2004). Other related literature also reveals that the implementation of lean thinking brings benefit to healthcare

Fig. 1 Lean principles and aims of healthcare quality (adapted from Inozu et al. 2012; Black 1984)



(DeKoning et al. 2006; Jimmerson et al. 2005; Young and McClean 2008; Ahluwalia and Offredy 2005). It has been emphasized that lean thinking provides the following benefits (Jones and Mitchell 2006):

1. *Improved quality and safety*—fewer mistakes, accidents and errors, will result and better quality goods and services will be produced.
2. *Improved delivery*—the work gets done faster.
3. *Improved throughput*—the same people, using the same equipment, find they are capable of achieving much more results.
4. *Accelerating momentum*—a stable working environment with clear, standardized procedures creates the foundations for constant improvement.

The customers for healthcare services are mainly patients but also include society, government, or even the legislations. The quality aims proposed by IOM (2001) comprises the main values required by the customers. Any activity or step that contradicts, prevents, or shifts attention from any of these aims is considered as non-value adding activity and should be targeted for elimination as required by value stream principle. Perfection should be targeted to achieve all the quality aims. Lean principles “flow” and “pull” deal with the healthcare quality aims “timely” and “efficient”. All lean principles are patient-centred (Fig. 1).

Challenges Faced by Lean Thinking

Like any other improvement philosophies or approaches, lean thinking faces a range of criticisms both from philosophical and practical perspectives (Hines et al. 2004; Powell et al. 2009). Powell et al. (2009) list 13 particular challenges in applying lean thinking

in healthcare settings as identified by various authors. Most of these challenges are similar to these challenges that have been facing manufacturing organizations before or during the application of lean thinking. Having complex patient pathways in healthcare services is a factor that may contribute to the importance of applying lean thinking rather than the opposite. Powell et al. (2009) state in their list that Just-in-time requires demand prediction. This is not a true statement. The pull strategy of Just-in-time is particularly designed to deal with real demand rather than predictions or forecasts (Simchi-Levi et al. 2008). Nevertheless, the study of the NHS Institute for Innovation and Improvement stresses demand on healthcare is mostly predictable with a range (Westwood et al. 2007). The study emphasizes that it is the way the process is designed and operated that causes any instability that is important to note.

Falling to understand the real challenges is one of the main reasons that limit the application of lean thinking in healthcare services and in particular in areas such as operating rooms or in dealing with the actual work of medical professionals. Understanding these challenges allows us to adapt lean thinking to suit the healthcare settings. We should first look to the main differences between healthcare and manufacturing settings. These differences are summarized below.

Differences Between Healthcare and Manufacturing Settings

Hospital and manufacturing production systems vary in a number of dimensions. There are several reasons for the notion that the concept of lean thinking should be adapted to fit the hospital system (Woodward-Hagg et al. 2007). Gong (2009) considers the work of Al-Hakim (2006) and lists major areas of differences between manufacturing and healthcare settings. The differences include human involvement, level of product uniformity, cycle time, waiting time, object behaviour, ease of performance measurement, and process effectiveness.

Advanced machinery could be designed and then skilled labour involvement could be minimized in a manufacturing setting; whereas, in healthcare, involvement of skilled professionals is necessary. In manufacturing, performance of workers in the production process is easier to measure. In contrast, performance of professionals in the process is not easily measurable. Again, this is because healthcare professionals differ in skills and expertise, and it is hard to measure their effectiveness in dealing with various complexities during operation processes. Also, products have defined characteristics in manufacturing; however, in healthcare, since the level of complexity and variability of activities is high, it is not always possible to predict the degree of the success of surgery.

In addition, while products are uniform in manufacturing, every patient may require a different service in healthcare. Even health problems that appear to be similar could require a unique treatment. As a result, the designed process needs to be modified to fit the circumstances of each particular patient. Also, unlike manufacturing products which have defined characteristics, patients' behaviour is not predictable and could vary substantially.

Table 4 Summary of differences between the manufacturing and healthcare services settings (Gong 2009)

Organization type		
Differences	Lean thinking in manufacturing	Lean thinking in healthcare
Human involvement	Automation is a major role to reduce human involvement; it reduces the need for high skill and knowledge	Skill, knowledge, and experience of professionals play major role
Ease of performance measurement	Performance of workers in the production process is easy to measure	Performance of professionals in the process is not easily measurable
Process effectiveness	Process outcome is predictable	It is hard to predict the degree of the success of healthcare service
Product uniformity	Machine produces identical products	It is difficult to perform a medical operation (say surgery) that will have exactly same output. In addition, every patient requires different service
Object behaviour	Products have defined characteristics	Patients' behaviour is not predictable and could vary
Cycle time	Cycle time of the production could be precise and determined in advance	Healthcare service cycle time could vary and is difficult to determine prior to the service
Non-added value activity time	All types of inspection are waste and should be reduced or eliminated	In healthcare environment, monitoring and testing are essential
Information flow	Mainly depends on process flow	Healthcare activities are information-based activities

Further, production cycle time could be precise in a production setting, but it is not possible to fix an operation time in healthcare as each service might be unique. Also, zero waiting time could be targeted in a manufacturing environment; whereas waiting time is not always a waste in healthcare. Sometimes it can even be considered as a value-added activity. If an operating theatre of the hospital is taken as an example, an anaesthetist does the job mainly at the beginning of the operation, while the other surgical team is involved in monitoring activities. In contrast, in a production line of manufacturing, if a worker is waiting or monitoring a process, it is considered as a waste that should be eliminated to improve efficiency (see Table 4 for summary of differences).

Considering that modern lean thinking deals with human factor aspects, most of the main listed differences can be managed including human involvement, performance measurement, and object behaviour. Similar to any service process, information flow plays major role besides human (employees) involvement (Evans and Lindsay 2008). Several important differences missed from the list of Gong (2009), among them are that the patient (customer) is directly involved in the healthcare services and the healthcare services are consumed and produced simultaneously (Evans and Lindsay 2008). Another important difference missed from Gong's list is

that the defect as a waste could result adverse event that is very costly and cannot be rectified. Performing surgery in the wrong side (removing the wrong breast or cutting wrong leg) cannot be rectified by performing corrective action or repeating the wrong activity. Defect even can be vital and may lead to death. This is not the case in manufacturing or other service settings. It is the value principle, particularly safety factor, forms the main difference between healthcare and other settings. From lean thinking perspective, value should be specified by customers. Value stream should stream activities of the process throughout the patient journey within the processes in order to identify non-value adding activities and eliminate or reduce them. The quality aims provided by IOM (2001) specifies these values as shown in Table 2. The first aim, i.e. safe, is specifically critical value from customer perspective. The safe principle may require changes in the definition of waste, in some circumstances may be different from waste as defined for the purpose of applying lean thinking settings other than healthcare service. For instance, monitoring may be considered as waste from manufacturing perspective while it could be extremely important in certain healthcare services such as monitoring patients inside intensive care units. The position of the scrub table inside operating room is another example. From manufacturing perspective, having scrub table near the door of the operating room may have logistical advantage as there is wide range of circumstances in which there are needs to bring sterilized materials or instruments from outside operating rooms to the table during surgery. Opening or closing OF doors may generate airborne contamination. In addition, having scrub table near the door increases the movements around the table and subsequently increases airborne contamination. What could be considered as logistical waste from manufacturing perspective may create value from healthcare perspective. This fundamental difference requires us to look to value stream from customer value as specified by IOM (2001) and not by the traditional perspective adopted for other settings. According to the NHS study (Westwood et al. 2007), identifying the value stream means identifying the components of the patient journey which add value to their care. This can be done through process mapping. Most current process mapping methodologies deal with work flow and from which the information flow can be identified. These methodologies are suitable for manufacturing as well as the majority of service settings. Healthcare service is an information-based service (McLaughlin 1996). Accordingly, information flow plays a major role in healthcare services. This fact creates another major difference with other setting where the work flow plays a major role. This fundamental difference leads us to search for methodology that first maps information flow in order to identify the components of the process rather than the opposite. Lillrank (2003) suggests that the primary problem in healthcare services is not the quality of the actual implementation of the process, such as surgery, but the quality of information that controls the process. The recognition of data and information quality becomes a key area of both strategic and operations management in the healthcare industry (Lorence and Jameson 2002). This adds another difference in that the information quality and the quality of information flow play more superior role than in manufacturing settings where machines, automation, and quality of work flow are more important. Table 5 shows the main additional difference between

Table 5 Additional difference between manufacturing and healthcare settings that requires adaptation or more attention

Lean thinking principle	Issue	Manufacturing settings	Healthcare settings
Customer value	Customer involvement	Customers are not involved in manufacturing the product	Customers are directly involved in producing the services
	Waste: defect	Defect in manufacturing is rectifiable. It may require repletion of the process	Defects could result adverse event that is very costly and cannot be rectified
	Waste: definition	Waste is any activity or activities that a customer would not want to pay for, and that do not add value to the product or service from the customer's perspective	Similar definition. However, the activities which may be considered waste in manufacturing setting may not be considered waste from healthcare perspective
Value stream	Consumption	Products are produced and consumed at a later stage	Products are produced and consumed simultaneously
	Basis of the processes	Work-based process	Information-based process
	Quality	The primary quality problem in manufacturing settings is the quality of the final product	The primary problem in healthcare services is not the quality of the actual implementation of the process but the quality of information that controls the process (Lillrank 2003)
	Process mapping	Requiring methodology that first maps the components of work flow	Requiring methodology that first maps the information flow in order to identify the components that add value
Flow	Priority	Priority is given to work flow	Priority is given to information flow

healthcare and manufacturing settings that needs further attention and more adaptation from lean thinking perspective.

Applications of Lean Thinking in Healthcare Services

As the proceeding has hopefully highlighted the area of lean for healthcare is both broad and rich. Given the importance for healthcare delivery today to grapple with challenges such as escalating costs, demands for high-quality care, ageing

populations, increase in chronic diseases such as diabetes as well as the increase in technology, it becomes more essential than ever before for healthcare organizations to embrace the principles of lean and adopt many of the related tools, techniques, and practices to effect superior healthcare delivery. The following pages serve to guide the reader through the complex and rich world of lean thinking for healthcare. We do this by first introducing key principles, concepts, techniques, and technologies in Part I. Then in Part II we present the reader with a miscellany of applications taken from various healthcare contexts throughout the world which serve to highlight either the benefits of applying lean thinking and/or how lean thinking principles may have facilitated a better and more successful result. Parts III and IV, respectively, serve to illustrate macro-level and micro-level considerations with regard to the application of lean thinking in healthcare contexts and finally Part V provides case studies that demonstrate the benefits of simulation in various emergency departments in order to illustrate how lean thinking can actually facilitate current state operations, streamline workflow, and enable heightened healthcare value to be realized.

The world of lean thinking for healthcare is still at its infancy. It is a very broad and rich world and thus it is not possible to fill the pages of one book with all possible scenarios and contexts. However, we hope this book will provide our readers be they academics or practitioners, graduate students or members of the general public all with one common desire to understand how to create and support superior healthcare delivery by applying lean thinking for healthcare, a road map to illumination and thereby the getting of better healthcare delivery for us all.

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