Rev Bras Anestesiol. 2019;69(5):502–509

Sociedade Brasileira de Anestesiologia

REVISTA BRASILEIRA DE ANESTESIOLOGIA

Publicação Oficial da Sociedade Brasileira de Anestesiologia
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REVIEW ARTICLE

Lean Six Sigma and anesthesia

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Received 1 May 2018; accepted 10 December 2018
Available online 22 October 2019

KEYWORDS
Lean Six Sigma;
Management;
Anesthesiology;
Operating room

Abstract
Background: Demands for health services have been growing sharply. Consequently, the costs of the institutions for their operational maintenance and investments also increase. The challenge of hospital management is to achieve standards of quality and safety for patients, increasing their productivity and minimizing costs. Lean Six Sigma is a well-structured methodology that aims to eliminate waste and activities that do not add value, focused on reducing process variation, eliminating the causes of the defect, and improving performance. As a result, cost reduction, higher quality, and customer satisfaction are observed.
Objectives: To define Lean Six Sigma methodology and search references in the literature on its use in Health and specifically in Anesthesiology.
Content: How often the waste of medicines, materials and time (rework), as well as the errors that happen in the day-to-day of the anesthesiologist are reported. Anesthesiologists must know the impact of their professional practice, with the purpose of making more appropriate choices, thus reducing the damage to the environment, improving overall health, and reducing costs with health care. The use of the Lean Six Sigma methodology is suggested to make the anesthesia field more sustainable, improving the processes without prejudice to the patient.
Conclusion: Lean Six Sigma methodology is a new business management strategy in the health area. It is perfectly inserted in the current context of quality and safety to the patient; therefore, relevant in the practice of anesthesiology.

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https://doi.org/10.1016/j.bjane.2019.09.004

PALAVRAS-CHAVE
Lean Seis Sigma;
Gestão;
Anestesiologia;
Centro cirúrgico

Lean Seis Sigma e anestesia

Resumo
Justificativa: As demandas por serviços de saúde têm crescido de forma acentuada. Consequentemente, crescem também os custos das instituições para sua manutenção operacional e investimentos. O desafio da gestão hospitalar é conseguir conquistar padrões de qualidade e segurança para o paciente, aumentar sua produtividade e minimizar os custos. Lean Seis Sigma é uma metodologia bem estruturada que visa a eliminar os desperdícios e atividades que não agregam valor, focada na redução da variação nos processos, elimina as causas do defeito, melhora o desempenho. Como resultado, observa-se redução de custo, maior qualidade e satisfação do consumidor.
Objetivos: Definir metodologia Lean Seis Sigma e buscar na literatura referências do uso da metodologia em saúde e especificamente na anestesiologia.
Conteúdo: Descreve-se como são frequentes os desperdícios de medicamentos, materiais e tempo (retrabalho), bem como os erros que acontecem no dia a dia do anestesiologista. O anestesiologista deve conhecer o impacto de sua prática profissional, com o objetivo de fazer escolhas mais apropriadas e reduzir assim o dano ao ambiente, melhorar a saúde global e reduzir os custos com assistência à saúde. Sugere-se o uso da metodologia Lean Seis Sigma para tornar a anestesia mais sustentável, com melhoria dos processos, sem prejuízo ao paciente.
Conclusão: A metodologia Lean Seis Sigma é uma estratégia de gerenciamento de negócio de fato nova na área da saúde. Insere-se perfeitamente no contexto atual de qualidade e segurança ao paciente, relevante, portanto, na prática da anestesiologia.

Introduction

Demands for health services have markedly grown and future prospects are for continuous expansion. Consequently, the costs of operational maintenance and investments of institutions also increase. The real challenge of hospital management is to achieve quality standards that are necessary not only to ensure adequate care but also to provide better competitive conditions and differentiated remuneration for institutions.

Due to increased demand, high care costs and limited resources the healthcare organizations need to become efficient, increase productivity, and minimize spending. The success of a hospital that holds quality certifications is fundamentally related to its ability to provide a continuity to the best practices in care and administrative management.

The current economic scenario has put pressure on healthcare and providers, including anesthetists, to minimize costs without sacrificing patient safety (a seemingly paradoxical measure).

For continuous process improvement, standards of excellence must be defined in advance and known to all those involved. Knowledge of what works well and what can be improved is essential.

Lean Six Sigma (LSS) is a well-structured methodology aimed at eliminating waste and non-value-added activities, focused on reducing process variation, eliminating defect causes, and improving performance. Consequently, cost reduction, higher quality, and customer satisfaction are seen as a result.

Healthcare professionals have accepted and implemented LSS in their organizations, which are quite different from car manufacturing from which the Lean philosophy emerged.

Delays, duplicate information, burnout, rework, unnecessary motion of patients and health professionals, and lack of equipment and supplies are factors that lead to the loss, dissatisfaction and frustration of people working in these sectors.

To understand what Lean Six Sigma is, we first need to understand what is the Six Sigma methodology.

Six Sigma is a business management strategy originally developed at Motorola in 1990 in the United States. This methodology is applied in many areas of industry and, from 1990 onwards, its use in health began.

Six Sigma seeks to improve the quality of process outputs by identifying and removing the cause of these defects (errors) and reducing variability in manufacturing and processes.

Sigma is a measure of variability used in statistics. This measure, applied to a business process, concerns the ability of the process to run flawlessly. When talking about Six Sigma, it means reduced variation in the result delivered to customers at a rate of 3.4 failures per million or 99.99996% perfection. The Six Sigma concept is a new way to measure how good a product is. A Six Sigma product implies that its quality is excellent, meaning that the probability of producing defects is extremely low.[1,2]

This methodology uses a variety of methods, including statistics as already mentioned. A special organizational

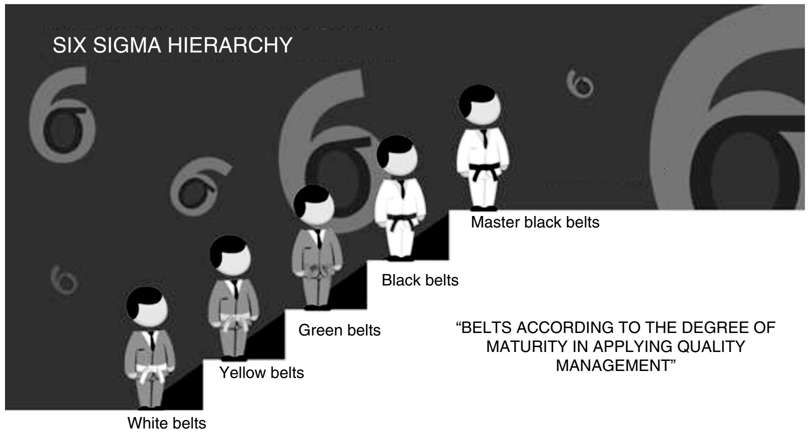

Figure 1 Six Sigma organizational hierarchy.

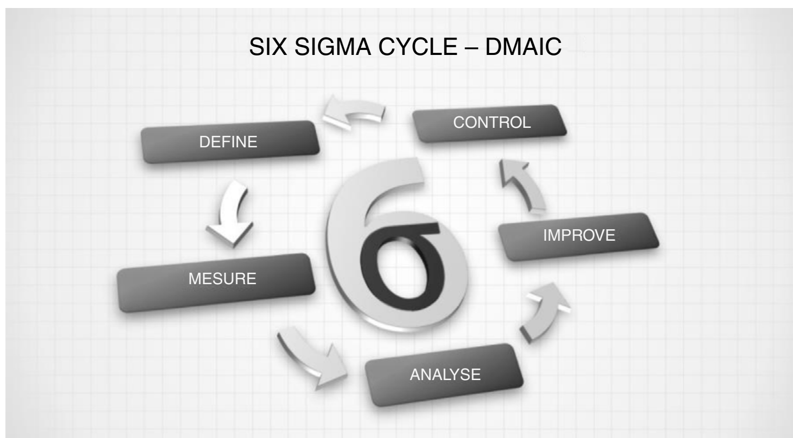

Figure 2 Six Sigma DMAIC cycle.

structure is created for people within the company with different hierarchical levels, represented by colored belts like those used in martial arts. The darker the belt, the more advanced is its level and degree of maturity to apply the quality management process (Fig. 1).

Each Six Sigma project developed within an organization follows a defined sequence of quantified steps and objectives (DMAIC roadmap steps). There are five steps that must be followed and completed to ensure the project progress (Fig. 2).

The first step is to define the problem (Define), followed by current state measurement (Measure), identification of root causes (Analyze), development and testing (Improve) and, last but not least, the implementation of changes (Control), ensuring that results will remain in the future (Fig. 3).[1,2]

These goals can be financial (cost savings and profit increase) or any aspect that is critical to the end consumer (value creation, safety, durability, etc.).

A few years ago, supporters of the Six Sigma methodology combined with the ideas of Toyota Lean Manufacturing to create a methodology that is called Lean Six Sigma (Fig. 4).

The methodologies are complementary and have the following characteristics:

Six Sigma:

- Emphasizes the need to recognize opportunities and eliminate defects as defined by consumers;
- Recognizes that variability hinders our ability to deliver high-quality services;
- Requires data-driven decisions and incorporates a complete set of quality tools under a powerful framework for effective problem solving;
- Provides a highly durable cultural infrastructure for sustainable results;
- When deployed correctly, it promises profit in operations.

Lean:

- Focus on maximizing process velocity;
- Provides tools for analyzing process flow and delays in each process step;
- Centers on the separation of ''value added'' from ''non-value added'', has several tools to eliminate the root cause of non-value added activities and their costs.

The eight types of waste (or non-value added activities) are:

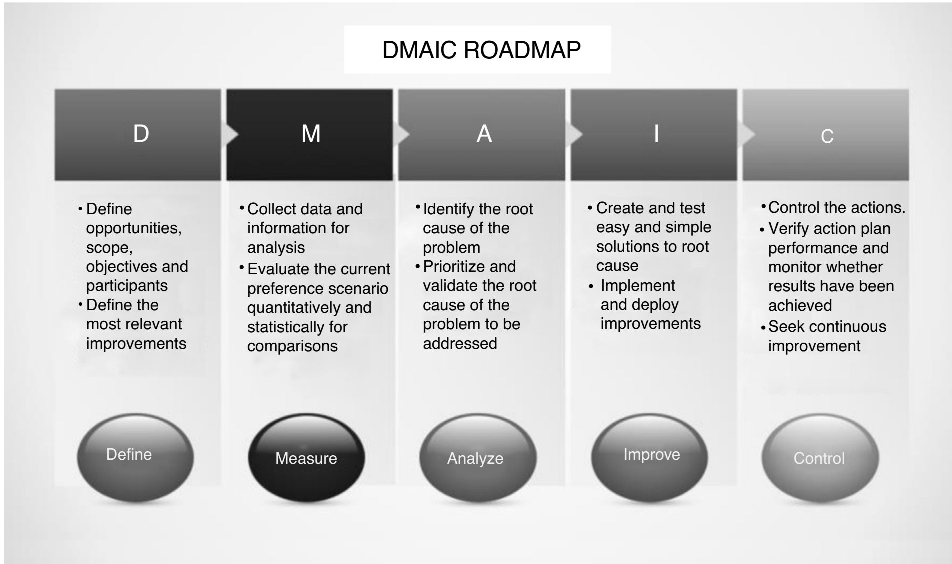

Figure 3 DMAIC roadmap.

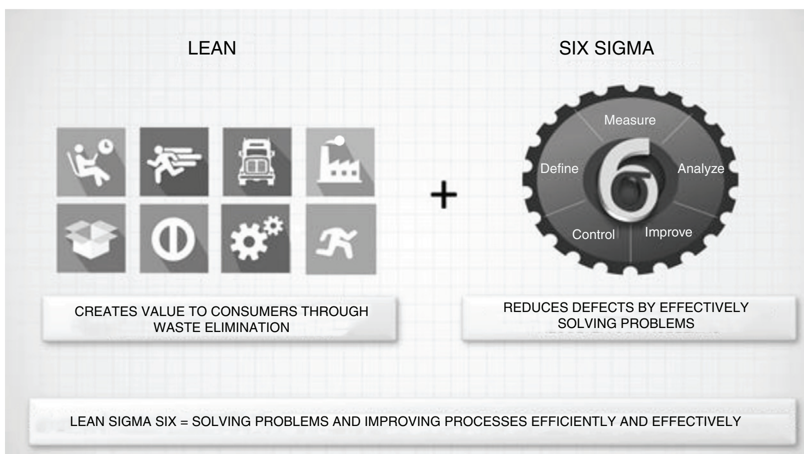

Figure 4 Lean+Six sigma methodology.

- Waste of manpower;
- Defects/things that are not correct and need repair;
- Inventory/things waiting to be worked on;
- Overproduction/too much or too soon;
- Waiting time/people waiting for things to arrive;
- Unnecessary human motion;
- Transport/motion of people and things;
- Process Waste/things we must do that do not add value to the end product or service we provide (Fig. 5).[1,2]

Mason et al. (2014) published a systematic review on the use of the LSS methodology in surgery. Twenty-three publications were found, but only six studies used the combined association of Lean and Six Sigma.[3] These six studies aimed to improve operating room efficiency, reduce patient injury (surgical complications), reduce mortality, and limit unnecessary costs resulting from prolonged hospital stay.[4–9]

In Saudi Arabia, Lighter (2014) described the LSS methodology in a pediatric hospital, and Almorsy and Khalifa (2016) improved the use and decreased the waste of blood glucose band by applying the DMAIC methodology.[10,11] Quality improvement in pain control of hospitalized patients using the same methodology was described by Droullard et al. (2017).[12]

Kruskal et al. (2012), Lee et al. (2014), and Amaratunga & Dobrnowski (2016) published works using LSS in radiology.[13–15] LSS was used at an invasive cardiology center by Agarwal et al. (2016), otorhinolaryngology clinic by Lin et al. (2013), and ophthalmology clinic by Ciulla et al. (2017).[16–18]

Molla et al. (2018) published in the Journal of Quality and Safety of the Joint Commission an article that proves the improvement of hospital turnover when the LSS methodology is applied.[19] However, few publications reported the specific use of the LSS methodology in anesthesiology.

Kuo et al. (2011) propose the use of the LSS methodology to improve the Post-Anesthesia Care Unit (PACU) process, but it was a theoretical proposal.[20]

Figure 5 The eight kinds of Lean waste.

Haenke and Stichler (2015) also applied the methodology at PACU. They increased the number of beds, improved workflow, offered better patient care, and saved a large amount of money as they decreased unnecessary nursing service and reduced patient stay in PACU.[21]

Roberts et al. (2017) improved the process of pediatric anesthesia in a Washington DC hospital, decreased the unnecessary circulation of nursing staff looking for materials used in the anesthetic procedure.[22]

Stonemetz et al. used the LSS methodology at Johns Hopkins Hospital (Baltimore/USA) and achieved a significant reduction of hospital garbage, saving over $500,000 for the institution, and encourage anesthesiologists to participate in improvement projects, in addition to direct patient care, aiming at financial gain.[23]

The following are subjects related to anesthesiology that could be used in project design using the LSS methodology.

A study performed at a university hospital in Brazil found that the operating room is one of the main sectors in which hospital waste occurs.[24] This is a sector that uses much of the material resources and also has a highly complex logistics distribution. It is the main working environment of the anesthesiologist.

Waste is defined as any and all resources spent beyond what is strictly necessary to perform a service or make a product (raw material, materials, human resources, time, money, energy, etc.). Waste adds additional costs to the product/service without bringing any kind of improvement to the customer.

Avoidable waste is defined as the relationship between behavior of health staff and management culture of organizations, therefore modifiable (material that should not be opened, i.e., those with total loss of the quantity contained in the package by early and/or inadvertent request). However, the ''unavoidable waste'' is considered to be the material that, due to the quantity in packaging (according to industry production), there was no need to use all items, with loss of only a few items in the package.

Time spent on unsuccessful processes and on rework is also considered waste. Chargeback is an activity considered as rework. All chargeback/returned materials must be returned to their storage location, which uses the time of the operating room supply area staff. Chargeback is intrinsic to the working process of surgical kits because, even with all defined and delineated surgeries processes, when it comes to health services there are variations from individual to individual, surgeons, patients, and pathologies, which makes the process of preparing kits 100% unfeasible. This waste is inherent in the process of managing consumables in surgery, but should be minimized as much as possible.

Anesthesia-related waste in the operating room includes items such as material, medications, anesthetic drugs, and medical gases, not to mention the waste of time related to waiting (whether patient or surgeon, waiting for cleaning and preparation in the operating room or waiting for supplies unavailable at the time of anesthesia).[25,26]

Garbage has become the greatest symbol of waste. Much of what is wasted goes to the garbage can.

The amount of garbage produced in a simple 90-min routine surgery produces more waste than a family of four produces in a week.[27] The Association of Anaesthetists of Great Britain and Ireland estimates that each operating room produces approximately 2300 kg of anesthesia-related waste and 230 kg of sharps per year that would be incinerated at a cost of £750/ton. However, 40% of this waste could be reclassified as ordinary waste (costing £80/ton) or recycled (saving £15/ton), which would save the institution.[28]

Hubbard et al. (2017) improved the disposal of garbage in the operating room and obtained an estimated cost reduction around US$2200 per year.[29]

Zuegge (2013) emphasizes the importance of adopting more ecological and economic practices in our profession.[30]

The American Society of Anesthesiologists (ASA) in a recent publication (2016) invites anesthesiologists to think of a more sustainable daily practice with less waste, less production of trash, and more environmentally friendly.[31]

The waste of anesthesia-related drugs occur when they are diluted and unused, discarded due to poor sizing of vials that are supplied by laboratories or left over at the end of an anesthetic procedure.

Anesthetic drugs constitute 5–15% of the hospital pharmacy budget and 4% of the surgical procedure cost.[32] There is some pressure from the administration to reduce these costs, often limited to the choice of anesthesiologists regarding the use of certain neuromuscular blocking agents, antiemetics, and opioids.[33]

The study conducted by Weinger identified an average cost per case of discarded drugs of US$10.86 per patient. The drugs that most contributed to this waste were phenylephrine (21%), propofol (15%), vecuronium (12%), midazolam (11%), labetalol (9%), and ephedrine (9%).[34]

The greatest waste occurs in pediatric anesthesia. Drugs are diluted and wasted, although they have been partially used. It was found that 80% of epinephrine, ephedrine, naloxone, flunitrazepam, and cisatracurium were wasted, with rocuronium and nalbuphine being the ones that drew more attention regarding cost.[35]

In addition to drugs, anesthesiologists use other devices that are potential sources of waste. These include disposable laryngeal masks and tracheal tubes when they are opened and not used. The use of disposable contamination barrier filters in Brazil and in many European countries avoids the waste produced by plastic ventilating circuits that are usually discarded in the US.[36,37] Consideration should also be given to disposable surgical drapes, clothing gown, and single-use thermal blankets.[38]

McGain et al. (2017) compared financial costs and environmental impacts in five scenarios and employed single-use and reusable anesthetic equipment in an Australian hospital. In the scenario in which the materials were reused, they observed savings of £18,000/year; however, regarding the environment, there was 10% more CO_2 emission and the water use doubled.[39]

When it comes to preanesthetic evaluation, it is often observed that tests are required unnecessarily. The request for these tests rarely changes the conduct, but burdens the institutions and the patients. Good practice recommends conduct based on specialty guidelines, thus avoiding legal charges.[40]

Pollution from anesthetic gases results from small amounts of volatile anesthetics (nitrous oxide and halogenated anesthetics) that leak from the patient's breathing circuit into the operating room during anesthetic procedures. It may also be the gases exhaled by patients in the PACU. These waste gases present in the ambient air appear to be associated with diverse occupational hazards in the short and long run, besides having effects on the ozone layer, which leads to global warming.[41,42]

Deng et al. (2018) recently published a review on this subject and recommend a series of preventive strategies, as the conclusions regarding the deleterious effects on exposed professionals are uncertain. They recommend the use of adequate anti-pollution systems, operating room ventilation systems, induction of inhalational anesthesia with well-adapted masks, low fresh gas flow, and use of appropriate vaporizer filling device.[43]

Rinehardt and Sivarajan (2012) published a paper with considerations related to costs and waste in anesthetic practice. The authors attribute a higher cost to total intravenous anesthesia (5–10 times more expensive) compared to inhaled anesthesia with sevoflurane and desflurane associated with antiemetics. They state that isoflurane inhalation anesthesia is 10–25 times less expensive than inhalation anesthesia with faster emergence anesthetics (sevoflurane and desflurane) and that this earlier emergence has no impact on the end of PACU stay costs.[33] Such statements deserve careful consideration because the prices of drugs and technologies used at the time of publication were different from those currently practiced.

Anesthesiology is the only medical specialty that prescribes, dilutes, and administers drugs without conferral by another professional. Adding to the high frequency of drug administration, an error-prone environment is created, thus causing an adverse event.[44]

Adverse event is defined as an unintentional injury or damage resulting in temporary or permanent disability or dysfunction and/or prolonged stay or death consequently to the health care provided. Medication errors are the most common causes of patient morbidity and mortality.[45] The impact ranges from no harm to serious adverse effects, including death. The financial impacts on the institution and on all those involved must be mitigated.

In 2010, the Anesthesia Patient Safety Foundation (APSF) Consensus recommended practices to improve the safety of drug administration in the operating room.[46] Errors may occur for several reasons: lack of experience, poor surveillance, labeling, identification, improper selection, and fatigue inattention. Jensen et al. propose 12 measures to prevent these types of errors. These are measures related to labeling, preparation, and storage of syringes.[47]

Dhawan et al. (2017) believe that electronic and digital concepts should be incorporated to encourage the evolution of the anesthesia-related drug delivery system.[48]

The Societé Francaise d'Anesthésie et de Réanimation (SFAR) recently published guidelines (2017) to prevent medication errors in anesthetic and intensive care unit.[49] Events must be reported so that preventive and corrective measures can be taken.[50]

Anesthesiologists should be aware of the impact of their professional practice in order to make more appropriate choices, thereby reducing environmental damage, improving overall health, and reducing healthcare costs.

Finally, considering the statements above, the LSS tool was found to be a precious methodology that fits perfectly into the current context of quality and patient safety, therefore relevant in the daily practice of anesthesiology.

Conflicts of interest

The authors declare no conflicts of interest.

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