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The usefulness of lean six sigma to the development of a clinical pathway for hip fractures

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Abstract

Aims and objectives The objective of this study was to show the usefulness of lean six sigma (LSS) for the development of a multidisciplinary clinical pathway.
Methods A single centre, both retrospective and prospective, non-randomized controlled study design was used to identify the variables of a prolonged length of stay (LOS) for hip fractures in the elderly and to measure the effect of the process improvements – with the aim of improving efficiency of care and reducing the LOS.
Results The project identified several variables influencing LOS, and interventions were designed to improve the process of care. Significant results were achieved by reducing both the average LOS by 4.2 days (–31%) and the average duration of surgery by 57 minutes (–36%). The average LOS of patients discharged to a nursing home reduced by 4.4 days.
Conclusion The findings of this study show a successful application of LSS methodology within the development of a clinical pathway. Further research is needed to explore the effect of the use of LSS methodology at clinical outcome and quality of life.

Introduction

Lean six sigma (LSS), a combination of lean production [1] and six sigma [2], is a method developed in the industry, to improve quality, reliability, flexibility, delivery and efficiency of processes. More recently, in health care LSS is used as well, to improve the organization and quality of care [3,4] and to reduce costs [5,6]. In our hospital, we first used the method to reduce the length of stay (LOS) of the whole group of trauma patients [7]. We then examined its usefulness for several other issues. The aim of this paper was to show the usefulness of LSS for improving the efficiency of clinical pathways (CPW). The rapidly growing group of elderly patients with hip fractures was selected for this purpose. To improve the quality of care to this group, the process of giving care has to become more efficient.

Osteoporotic hip fractures in the elderly are recognized as one of the global major public health problems and are associated with considerable financial costs for hospitals [8–10]. More than 80% of the costs are related to ward costs. This emphasizes the growing economic impact arising from the (reduction of) LOS of inpatient treatment of hip fractures [11]. Strategies to improve the efficiency and consequently to reduce costs by improving the utilization of equipment, personnel and facilities are needed. In theory, physicians should always produce the greatest increment of patient health, using a sequence of services, in a specific time-frame, given a specified available budget [12]. Hospitals use CPW to improve the organization of care [13–15]. CPW are structured multidisciplinary care plans used by health services to detail steps in the care of patients with a specific clinical problem [13]. CPW try to achieve optimal clinical results with efficient procedures, which are continuously improved with plan-do-check-act cycles [16]. It has been established that CPW are effective methods to reduce LOS significantly [17,18] and to organize a hip fracture programme [19,20]. This paper describes how we used LSS as a tool for supporting the development of a clinical pathway.

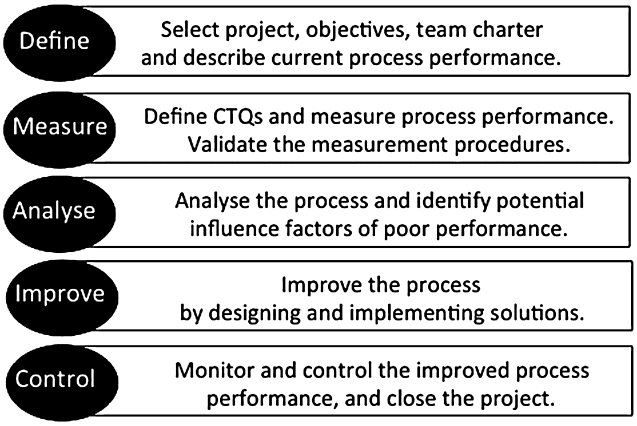

Figure 1 Lean six sigma DMAIC (define, measure, analyse, improve, control) roadmap. CTQ, critical to quality.

Methods

This single centre, prospective, non-randomized controlled study was conducted at the Departments of Traumatology and Orthopedic Surgery at the University Medical Centre Groningen, the second largest hospital of the Netherlands. The two departments have 62 beds available for acute and elective care and admit approximately 2350 patients a year.

In 2007, the board of the hospital introduced LSS as a method to improve organizational quality and to reduce costs. Several employees were trained to become an LSS project leader, to improve processes as part of their jobs. LSS offers the roadmap of DMAIC (define, measure, analyse, improve, control) [6] as an improvement methodology and a conceptual organizational framework with specific roles for project leaders ('black and green belts' in LSS terms) and project owners ('champions') to improve processes. The phases of the DMAIC roadmap are briefly described in Fig. 1.

The DMAIC phases are mile stones for the improvement project and integrate statistical quality tools and techniques like failure mode and effect analysis and statistical process control [21]. Process and outcome measurements are combined with project metrics into a systematic review process, so that management can manage the progress of the projects [22]. The medical staff of the Departments of Traumatology, Orthopedics, Geriatrics, Anesthesiology, and a nursing home decided in 2008 to develop a multidisciplinary clinical pathway as a collaborative care programme for elderly patients with a hip fracture, to streamline the care process, to improve quality of care and clinical outcomes, and to reduce LOS and costs. The assignment to reduce LOS was given to the chief nurse of the orthopaedic ward. She was inspired by successes of earlier LSS projects [7] and she took up the challenge of integrating LSS with improving CPW. In the following we describe the five DMAIC phases. We discuss the results in the next section.

Define

The aim of the project was to use the LSS method to improve the efficiency of a clinical pathway. The DEFINE phase of the DMAIC roadmap is concerned with defining the problem to be solved. That we had a problem was obvious from the bed occupation rates (97 and 89% at the trauma and orthopaedic wards, respectively) and frequent unavailability of beds to admit new patients. The project charter determined the project leader (chief nurse of the orthopaedic ward), process owners (trauma surgeon and medical head of the trauma department), scope, timeline and auxiliary members of the project team. To put the problem in perspective, a SIPOC (Supplier, Input, Process, Output, Customer) was made, leading to a detailed flowchart of the process at micro level. The process leader did a stakeholder analysis, to chart the stakes and the influence of the people involved.

Measure

To quantify the current process performance, we needed appropriate measurements, the so-called *critical to quality* (*CTQ*) indicators in LSS terms. A *CTQ flowdown* was used to translate the rationale underlying the project into performance indicators and strategic focal points [23]. The CTQ flowdown resulted in a measurement plan to determine the current performance of LOS, the number of clinical intakes and throughput time of the (main) process. The strategic focal points were: capability for admittance to the hospital from the perspective of the patient and increasing revenue from the perspective of the hospital. According to the measurement plan a retrospective data collection (2006–2007) was obtained from the digital information system. This data (including patient characteristics, LOS and throughput times) was validated by a comparison with the paper files of a random sample of 20 patients. In 2006 and 2007, 137 patients with an isolated hip fracture were admitted. Exclusion criteria were multiple injuries, acute cerebral vascular accident and in-hospital mortality ($n = 7$).

A second dataset was obtained prospectively from all admitted patients in the period November 2008 to January 2009. This data was used to make a *value stream map* [6] of the current process performance with information about *workflow* (process times) and *waste* (waiting times and other inefficiencies) (Fig. 2). The value stream map was determined from the patient's point of view.

A third dataset was obtained prospectively after the implementation of the clinical pathway (July 2009 to December 2010) to establish the effects of the improvement actions on LOS. During this period, data from 195 admitted patients were collected.

Analyse

The aim of the Analyse phase was to arrive at a data based diagnosis of the current process performance [6]. The LOS of patients in the retrospective dataset (2006–2007) was analysed with analysis of variance (ANOVA) techniques for categorical variables and regression analysis for continuous variables (age and duration of surgery) to identify significant influence factors (Table 2).

For the second dataset, we used descriptive data analysis to estimate process inefficiencies (cf. Fig. 2). And we identified potential improvement actions from exploratory data analysis: a few BOB (best of the best) cases were compared with a few WOW (worst of the worst) cases to find recurring patterns. The first observation was that no standard procedures and protocols of multidisciplinary intake existed, with the effect that the waiting time before admission to the nursing ward (NW) could be too long.

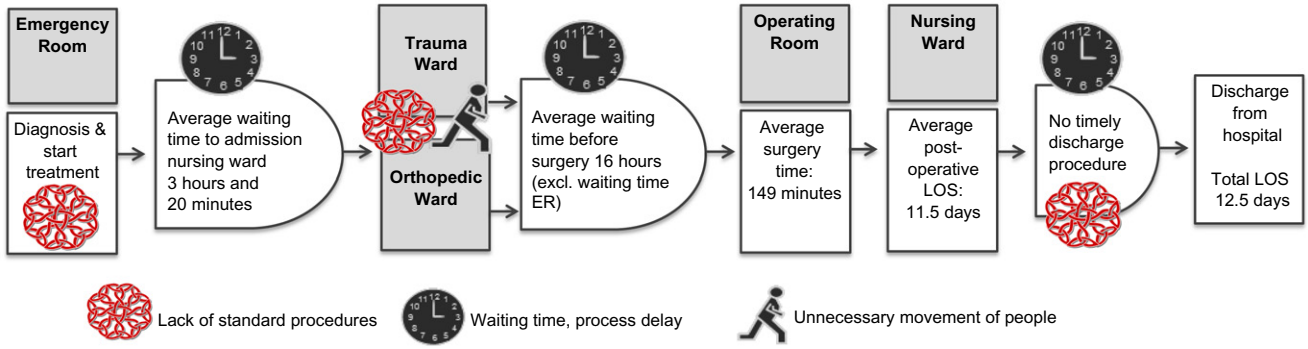

Figure 2 Value stream map of process performance November 2008 to January 2009. ER, emergency room; LOS, length of stay.

The second observation was that the preoperative consult of the anaesthesiologist took place at the NW and that (additional) diagnostic tests were performed depending on the co-morbidity, resulting in unnecessary movement of patients and personnel at the NW. The third observation was that the discharge procedure often started between 1 and 3 days after the operation, with the effect that the patient was discharged later than necessary.

Improve

After the process was diagnosed, the project team determined objectives for interventions to eliminate waste and to reduce waiting times, resulting in a reduction of LOS. The main characteristics of the interventions are standardization of work processes and care (Table 1).

In June 2009, the multidisciplinary teams started working according to the new standards of the clinical pathway.

Control

The new process is actively monitored, to assure that better results are retained. A specialized nurse compiles a prospective database with relevant data of every elderly patient with a hip fracture, to keep track of the care process. This database is used for the frequent multidisciplinary evaluations of the patients, and for examining the impact of the improvements. We use the prospective data from July 2009 to December 2010 to analyse the LOS before and after the interventions (using ANOVA).

Results

The retrospective data from 2006 and 2007 are used to set the baseline result. Table 2 shows the effects of potential influence factors on LOS.

The average LOS of elderly patients with a hip fracture was 13.5 days. Only the gender of the patient was a significant influence: female patients had higher LOS than male patients. We also investigated the effects of American Society of Anesthesiologists (ASA) classification and duration of surgery, defined as the time from starting the anaesthesia to wound closure. The ASA classification made no difference, but patients with surgery lasting more than 2 hours had significant higher LOS.

The observations during the project (the second dataset) revealed that the average LOS at the trauma ward decreased to 10.5 days ($n = 27$). The LOS at the orthopaedics ward was unchanged ($n = 16$). We also observed that the average LOS at the emergency room (ER) was 192 minutes. Almost all patients were operated within 48 hours, with an average waiting time of 28 hours and 57 minutes. The third dataset showed that LOS decreased even further after the implementation of the interventions. The overall average LOS reduced from 13.5 days before to 9.3 days after implementation of the clinical pathway (–31%). The financial reward of this LOS reduction amounts to annual cost savings of €120 000. Table 3 shows the influence of variables on LOS.

The average LOS decreased irrespective of discharge destination: nursing home –31% (–4.4 days), home –41% (–4.8 days) and others –37% (–3.5 days). Table 4 shows a comparison of demographic and surgery factors between the control group of the first dataset and the group of patients after the project (the third dataset).

The duration of surgery decreased significantly. After the interventions, 80% of the surgeries had duration of less than 2 hours. There were significantly more patients with ASA classifications 1 and 2 after the interventions. But the average LOS between the categories ASA 1 and 2 (8.4 days) and ASA 3 and 4 (10.1 days) was not significantly different ($P = 0.236$).

Discussion

The aim of the project was to examine the usefulness of LSS as a tool for improving efficiency in giving care to a specific group of patients. The LSS method was used to identify the most important variables influencing the LOS of a clinical pathway. The additional value of LSS is the combination of the use of a structured DMAIC roadmap, the conceptual organizational framework with specific roles during the project and the integrated use of quality tools and techniques. The systematic approach keeps you concentrated at the strategic focus points and the CTQs. The project charter creates ownership by medical doctors, a necessity for implementation of improvement actions. The analysis of the process, using statistical methods on valid and reliable data, gives an objective diagnosis of the current state. The most important influence variables are detected, and selected for improvement actions. Finally, the tools and structure to monitor the process are useful instruments for continual process improvement. The results of this study confirm

Table 1 Objectives and interventions for optimized care process

Current process	Planned interventions
Average waiting and treatment times of 200 minutes at the ER.	Standardized multidisciplinary procedure of the diagnostic process at the ER within 120 minutes.
Different protocols for intake by multidisciplinary team at ER and NWs.	Standardized protocols for intake and diagnostic tests by all multidisciplinary teams (traumatology/orthopaedics and anaesthesia) at the ER.
Different treatment protocols at the traumatology and orthopaedic medical and nursing departments.	Standardized treatment protocols for both medical and NW.
No standards for discharge planning.	Standardized discharge planning for both (NW): • Discharge planning starts within 24 hours after admission, but before operation. • Determination of a collaborative interdisciplinary rehabilitation programme of hospital specialists and the medical doctors at a specific nursing home. Each week the nursing home reserves two or three beds to admit new patients.
Average duration of surgery of 149 minutes	Average duration of surgery reduced by 60 minutes through: • A daily labelled schedule to operate patients with a hip before the starting time of earlier planned semi-elective surgeries. • The surgery is performed by or in presence of a senior surgeon.

ER, emergency room; NW, nursing ward.

Table 2 Effects of potential influence factors on LOS

Variable	*N*	LOS: average ± SD (median)	*P* value
All patients	137	13.50 ± 10.17 (11)	
Gender			
Male	42	10.33 ± 6.18 (8.5)	0.015*
Female	95	14.89 ± 11.24 (12)	
Age (years)			
<75	47	11.96 ± 7.64 (11)	
76–85	47	14.72 ± 11.20 (11)	0.316†
86–95	42	13.79 ± 11.49 (11)	
96–105	1	16	
Department			
Traumatology	90	14.26 ± 10.02 (12)	0.228*
Orthopaedics	47	12.04 ± 10.39 (9)	
Discharge destination			
Nursing home	93	14.42 ± 10.53 (12)	
Home	40	11.75 ± 9.53 (10.5)	0.279*
Others	4	9.50 ± 3.87 (8.50)	

*Analysis of variance.
†Regression analysis.
LOS, length of stay; SD, standard deviation.

the idea that LSS is a valuable method for redesigning the care process and for improving a clinical pathway.

The retrospective analysis of the first dataset indicated that female patients had a higher LOS than male patients. This result differs from Deakin *et al*. [24], who reported a significant higher risk for male patients of requiring discharge to a nursing home. Cultural aspects of a society might well be the reason for this difference. The duration of surgery was also important for LOS variation. Collins *et al*. [25] concluded that intra-operative factors generate the highest risk for a prolonged LOS; therefore, efforts should be made to improve the intra-operative process of care. As a result of the interventions at the intra-operative process, duration of the surgery decreased significantly. The second dataset showed that the average LOS of the elderly with a hip fracture at the traumatology department reduced with an impressive 27%. Another LSS project, to reduce inappropriate hospital stay for all trauma patients [7], was responsible for this result. The findings of that project were re-established in the BOB versus WOW analysis of this new project, and helped achieving more LOS reduction through further improvements of procedures for rehabilitation at and discharging to a nursing home. The average LOS of these patients reduced to 10 days.

This study deals with the efficiency of CPW. Other aspects of improvement in the quality of care are examined in another study. Nevertheless, process and structure quality influence patient's outcome and are inextricably bound up with patient's satisfaction and experiences of quality of care. Other studies (e.g. [25–27]) have shown the impact of separate and interactive factors such as complications to a prolonged LOS. Longer LOS is associated with an increasing risk of hospital-induced complications, for example enquired infections [28]. In our study, a patient with 38 days LOS shows that complications as (wound) infection are an important reason for prolonged LOS.

In spite of the limitations, we have demonstrated the value of LSS to improve the process of delivering care. Tables 3 and 4 show the

Table 3 Difference in LOS related to (influence) variables

Variable	*N*	Before ($n = 137$): average LOS ± SD (median)	After ($n = 195$): average LOS ± SD (median)	Difference average LOS %	*P* value
All patients		13.50 ± 10.17 (11)	9.3 ± 9.8 (7)	–31	0.000
Gender	Male	10.33 ± 6.18 (8.5)	8.59 ± 6.5 (7)	–17	0.173
	Female	14.89 ± 11.24 (12)	9.60 ± 11 (7)	–36	0.000
Age (year)	<75	11.96 ± 7.64 (11)	10.5 ± 14.23 (7.5)	–12	0.520
	76–85	14.72 ± 11.20 (11)	8.70 ± 6.50 (7)	–40	0.000
	86–95	13.79 ± 11.49 (11)	8.52 ± 3.73 (8)	–38	0.004
	96–105	16	5.5 ± 1 (5)	*	*
Department	Traumatology	14.26 ± 10.02 (12)	9.27 ± 6.55 (7)	–35	0.000
	Orthopaedics	12.04 ± 10.39 (9)	9.3 ± 14.16 (7)	–23	0.257
Discharge destination	Nursing home	14.42 ± 10.53 (12)	10 ± 10.99 (8)	–31	0.002
	Home	11.75 ± 9.53 (10.5)	6.95 ± 2,69 (7)	–41	0.002
	Others	9.50 ± 3.87 (8.50)	6 ± 1.41 (6)	*	*

LOS, length of stay; SD, standard deviation.

Table 4 Comparative demographics before and after implementation clinical pathway

Variable		Before project ($n = 137$)	After ($n = 195$)	*P* value
Gender (%)	Male	42 (30.7)	63 (32.3)	0.750
	Female	95 (69.3)	132 (67.7)	
Age years, mean (SD)	All	79.43 (9.77)	78.3 (9.38)	0.288*
Age years (%)	<75	47 (34)	74 (38)	0.491
	76–85	47 (34)	69 (35)	
	86–95	42 (31)	48 (25)	
	96–105	1 (1)	4 (2)	
Department	Traumatology	90 (66)	129 (66)	0.931†
	Orthopaedics	47 (34)	66 (34)	
ASA classification (%)	1–2	47 (34)	94 (48)	0.011†
	3–4	90 (66)	101 (52)	
Duration of surgery (minutes), mean (SD) (%)		154 (47.72)	98 (34.16)	0.000*
	<60	1 (1)	24 (12)	0.000†
	60–90	6 (4)	65 (33)	
	91–120	27 (20)	68 (35)	
	>121	103 (75)	38 (20)	
Discharge destination (%)	Nursing home	93 (68)	149 (76)	0.152†
	Home	40 (29)	44 (23)	
	Others	4 (3)	2 (1)	

*Analysis of variance.
†χ^2 test.
SD, standard deviation.

significant ($P = 0.000$) reduction of the average LOS and duration of surgery, respectively. We therefore conclude that the interventions were successful. The improved discharge procedure contributes substantially to delivering the right care at the right place.

The improvements do not lead to a reduction of the average LOS at the ER. The most important reason for the actual process delay is the fact that ER doctors treat patients with a hip fracture just like other patients in the ER. There is no preferred treatment and the average LOS for all patients on the ER is more than 3 hours. The goal set by the board of the hospital is to treat patients in the ER within 4 hours and with respect to that time path, 200 minutes is sufficient. Nevertheless the multidisciplinary standardized intake at the ER created a reduction of unnecessary movements of patients and personnel at the NW. Furthermore, care for patients are ameliorated because they are transferred on a hospital bed with anti-decubitus mattress on the ER already instead of lying on a stretcher.

Several limitations of this pilot study need to be acknowledged. The sample size is relative small and contextual factors, like the Dutch health care system, may have influenced the results. The external validity of the study can be improved by replicating the approach to create CPW for different groups of patients or in other contexts. In summary, the findings of this study suggest that LSS can be useful for the development of a CPW to identify (influence) variables of process of care and to manage the organization of care quantitatively.

References

1. De Souza, L. B. (2009) Trends and approaches in lean healthcare. *Leadership in Health Services*, 22 (2), 121–139.
2. Kumar, S. & Thomas, K. M. (2010) Utilizing DMAIC six sigma and evidence-based medicine to streamline diagnosis in chest pain. *Quality Management in Health Care*, 19 (2), 107–116.
3. Langabeer, J. R., DelliFraine, J. L., Heineke, J. & Abbas, I. (2009) Implementation of lean and six sigma quality initiatives in hospitals: a goal theoretic perspective. *Operations Management Research*, 2, 13–27.
4. Kenney, C. (2010) Transforming Health Care: Virginia Mason Medical Center's Pursuit of the Perfect Patient Experience. New York: Productivity Press.
5. De Mast, J. (2007) Integrating the many facets of six sigma. *Quality Engineering*, 19, 353–361.
6. De Mast, J., Does, R. J. M. M., De Koning, H. & Lokkerbol, J. (2012) Lean Six Sigma for Services and Healthcare. Alphen aan den Rijn: Beaumont Quality Publications.
7. Niemeijer, G. C., Trip, A., Ahaus, K. T. B., Does, R. J. M. M. & Wendt, K. W. (2010) Quality in trauma care: improving the discharge procedure of patients by means of lean six sigma. *Journal of Trauma*, 69 (3), 614–618.
8. Cooper, C., Campion, G. & Melton, L. J. III (1992) Hip fractures in the elderly: a world-wide projection. *Osteoporosis International*, 2, 285–289.
9. Roche, J. J. W., Wenn, R. T., Sahota, O. & Moran, C. G. (2005) Effect of comorbidities and postoperative complications on mortality after hip fracture in elderly people: prospective observational cohort study. *British Medical Journal*, 331 (7529), 1374–1379.
10. Parker, M. & Johansen, A. (2006) Hip fracture. *British Medical Journal*, 333 (7557), 27–30.
11. Lawrence, T. M., White, C. T., Wenn, R. & Moran, C. G. (2005) The current hospital costs of treating hip fractures. *Injury*, 36 (1), 88–91.
12. Donabedian, A., Wheeler, J. R. C. & Wyszewianski, L. (1982) Quality, cost, and health: an integrative model. *Medical Care*, 10 (10), 975–992.
13. Kinsman, L., Rotter, T., James, E., Snow, P. & Willis, J. (2010) What is a clinical pathway? Development of a definition to inform the debate. *Bio Med Central Medical*, 8, 31.
14. Müller, M. K., Dedes, K. J., Dindo, D., Steiner, S., Hahnloser, D. & Clavien, P. A. (2008) Impact of clinical pathways in surgery. *Langenbeck's Achives of Surgery*, 394 (1), 31–39.
15. Van Herck, P., Vanhaecht, K., Deneckere, S., Bellemans, J., Panella, M., Barbieri, A. & Sermeus, W. (2010) Key interventions and outcomes in joint arthroplasty clinical pathways: a systematic review. *Journal of Evaluation in Clinical Practice*, 16, 39–49.
16. Vanhaecht, K., Panella, M., van Zelm, R. & Sermeus, W. (2010) An overview on the history and concept of care pathways as complex interventions. *International Journal of Care Pathways*, 14, 117–123.
17. Rotter, T., Kinsman, L., James, E. L., Machotta, A., Gothe, H., Willis, J., Snow, P. & Kugler, J. (2010) Clinical pathways: effects on professional practice, patient outcomes, length of stay and hospital costs (review). The Cochrane Collaboration.
18. Vanhaecht, K., De Witte, K., Panella, M. & Sermeus, W. (2009) Do pathways lead to better organised care processes? *Journal of Evaluation in Clinical Practice*, 15, 782–788.
19. Pedersen, S. J., Borgbjerg, F. M., Schousboe, B., Pedersen, B. D., Jørgensen, H. L. & Duus, B. R. A. (2008) A comprehensive hip fracture program reduces complication rates and mortality. *Journal of American Geriatrics Society*, 56 (10), 1831–1832.
20. Kates, S. L., Mendelson, D. A. & Friedman, S. M. (2011) The value of an organized fracture program for the elderly: early results. *Journal of Orthopaedic Trauma*, 25 (4), 233–237.
21. Schroeder, R., Linderman, K., Liedtke, C. & Choo, A. S. (2008) Six Sigma: Definition and underlying theory. *Journal of Operation Management*, 26, 536–554.
22. Barney, M. (2002) Macro, meso, micro: six sigma. *The Industrial-Organizational Psychologist*, 39 (4), 104–107.
23. Niemeijer, G. C., Does, R. J. M. M., de Mast, J., Trip, A. & van den Heuvel, J. (2011) Generic project definitions for improvement of health care delivery: a case-based approach. *Quality Management in Health Care*, 20 (2), 152–164.
24. Deakin, D. E., Wenn, R. T. & Moran, C. G. (2008) Factors influencing discharge location following hip fracture. *Injury, International Journal of the Care of the Injured*, 39, 213–218.
25. Collins, T. C., Daley, J., Henderson, W. H. & Khuri, S. F. (1999) Risk factors for prolonged length of stay after major elective surgery. *Annals of Surgery*, 230 (2), 251–259.
26. Mc Aleese, P. & Odling-Smee, W. (1994) The effect of complications on length of stay. *Annals of Surgery*, 220 (6), 740–744.
27. Foss, N. B., Palm, H., Krasheninnikoff, M., Kehlet, H. & Gebuhr, P. (2007) Impact of surgical complications on length of stay after hip fracture surgery. *Injury, International Journal of the Care of the Injured*, 38, 780–784.
28. Schimmel, E. M. (2003) The hazards of hospitalisation. *Quality Safety in Health Care*, 12, 58–64.