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Use of Lean Six Sigma methodology shows reduction of inpatient waiting time for peripherally inserted central catheter placement

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ARTICLE INFORMATION

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AIM: The aim of this study was to assess the use of Lean Six Sigma methodology to improve the turnaround time (TAT) for inpatient peripherally inserted central catheter (PICC) placement.

MATERIALS AND METHODS: Value stream mapping was used to analyse the workflow process for inpatient PICC placement and to divide it into its component parts. Unnecessary steps were eliminated and variation minimised in the remaining processes. The TAT for PICC line placement was recorded for the 6 months prior to implementation of changes, and subsequently, at the 6-month and 2-year follow-up points.

RESULTS: Prior to implementing the changes, the mean TAT for PICC line placement was 3.74±3.28 days (95% confidence interval [CI]=3.3–4.17). Six months after implementation, the mean TAT was 1.89±1.82 days (95% CI=1.72–2.06, $p<0.0001$). The reduction was sustained such that at 2 years post-implementation the mean TAT was 1.88±1.87 days (95% CI=1.78–1.99, $p<0.0001$). This was achieved despite a 13.8% increase in overall interventional radiological activity.

CONCLUSION: By applying Lean Six Sigma methodology to the complex multifactorial processes involved from ordering a PICC to its final insertion, it was possible to identify areas for improvement and to introduce simple, effective measures that resulted in a significant sustained decrease in the TAT without additional resources.

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Introduction

"Lean" thinking and "Six Sigma" are quality improvement strategies that originated in industry.[1] The Lean concept focuses on the elimination of waste and the removal of unnecessary steps from a workflow process and was developed at the Toyota automobile manufacturing company in the mid-20th century.[2] Six Sigma also has its origins in industry, namely at the Motorola company, and seeks to eliminate the detrimental effects of variation within a workflow process.[3] Lean Six Sigma is a hybrid approach that seeks to dissect a workflow process into its component parts, eliminate any unnecessary steps, and reduce variability in the steps that remain. Lean, Six Sigma, and Lean Six Sigma have been applied successfully to

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several aspects of healthcare delivery.[4] Lean Six Sigma methodology has been applied within radiology predominantly with the goal of reducing waiting time for diagnostic investigations including outpatient computed tomography (CT)[5] and magnetic resonance imaging (MRI).[6]

Peripherally inserted central catheters (PICC) have become the standard of care for short-to medium-term venous access for hospital inpatients, with a recent study citing a 100% increase in the number of PICCs placed over the 2009–2015 period.[7] Delays in line placement can delay treatment and prolong patient admission. Increasingly hospitals are being tasked with delivering more with fixed resources. This can only be achieved by increasing efficiencies. This study was performed to assess the impact of Lean Six Sigma application on waiting times for inpatient PICC placement in a tertiary referral hospital.

Materials and methods

This was a prospective, before and after analysis of the efficiency of PICC insertion in an interventional radiology department based in an academic teaching hospital with a national referral base. This study was a quality improvement initiative, using anonymised patient data, and as such, it did not require ethics committee approval.

All inpatients referred for PICC insertion were included in the analysis. There was a 6-month pre-intervention period. Data were collected on the turnaround time (TAT) for PICC insertion. This was defined as the duration in days from a request for PICC insertion being placed on the hospital information system (HIS), to the procedure being completed and the "study complete" time being logged on HIS. PICC insertion is performed only within "office' hours (8.00 am–5.00 pm, Monday–Friday); however, the TAT was calculated from the actual time of the order being placed, even if overnight or at weekends. PICC insertion was performed by trainee radiology registrars in their year 2–5 of specialist training, under the supervision of five consultant interventional radiologists, all of whom had completed fellowship training in interventional radiology.

A thorough analysis was performed on the steps involved in PICC placement, both with regard to the patient flow from the ward to the interventional suite and to the handling of orders by the interventional radiology department. This allowed the creation of a value stream map (Fig 1) from which unnecessary, non-contributory steps and bottlenecks could be identified. Using the define, measure, analyse, improve, control (DMAIC) approach solutions were devised to individual barriers and limitations with the aim of process improvement.

Significant factors within the work stream with the potential to contribute to both delays and variation in the TAT were identified at all steps and are summarised below with the relevant measures taken to address them.

(1) Scheduling and transport deficiencies were identified as playing a role in significant delays, particularly at the beginning of the list. The interventional suite was underutilised in the first hour of the list each day. Priority was traditionally given to scheduling urgent/complex cases, with routine inpatient cases being deferred. No priority was given to patient transfer to interventional radiology prior to the intervention. Subsequently, porter services prioritised patients for transfer and two PICC insertions were scheduled as the first cases on the list each morning with the referring team and the ward notified the night before.
(2) Incomplete and/or incorrect completion of the request form for PICC insertion was recognised as a frequent contributory factor in delays. An electronic referral process was introduced in place of the previous paper-based system. The referral steps were streamlined and condensed.
(3) Very little patient preparation is required prior to PICC insertion; however, issues were identified regarding patient readiness for the procedure with patients frequently attending other hospital departments for treatment or investigations when sent for by the interventional department, or not having a valid consent form completed. This resulted in an opportunity cost with loss of procedural time. A "PICC checklist" of basic preparatory steps was devised and distributed to wards with an emphasis on patients being prepared the night before where possible.
(4) Significant day-to-day variation in PICC insertion was noted with the majority of procedures being performed on less specialised lists. With increased routine scheduling, PICC insertion was delivered more consistently with less variability over the week.
(5) A shift in the departmental cultural approach to PICC insertion was required with the value provided to patients and referring clinicians by timely access to PICC insertion being emphasised to all staff. Recognition of the contribution of individual staff members to service improvement was emphasised.

This analysis allowed the construction of a rationalised value stream map (Fig 2) with the elimination of unnecessary steps and streamlining of remaining steps. Specific unnecessary steps are outlined in Table 1.

No additional staffing or other resources were added during the study period. No other significant changes to either interventional radiology department workflows or the hospital porter system were introduced. The post-intervention study period was 6 months post-intervention, with additional analysis performed again at 2 years post-intervention.

Statistical analysis was carried out using GraphPad Prism Version 7 (GraphPad Software, San Diego, CA, USA). A Mann–Whitney test was used to analyse non-parametric data. A p-value <0.05 was considered to confer significance.

Results

Prior to the intervention, the mean TAT was 3.74±3.28 days. There was marked variation in wait times and in the

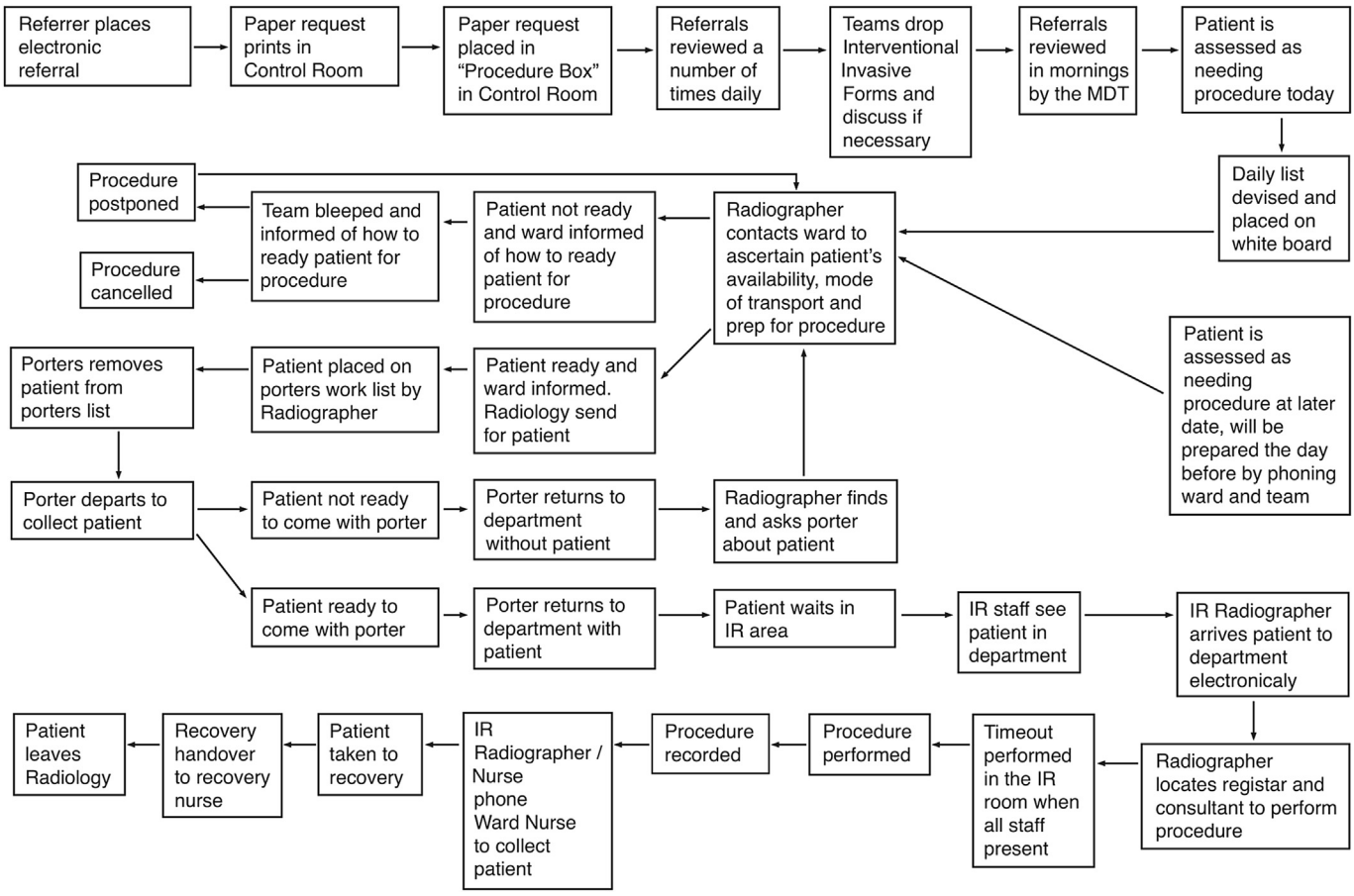

Figure 1 Value stream map for the PICC insertion process prior to application of Lean Six Sigma methodology.

number of PICCs being inserted per day, with 38% of patients waiting over 4 days from request placement to PICC insertion.

At 6 months post-intervention, the mean TAT had fallen to 1.89±1.82 days (95% CI =1.72–2.06, $p<0.0001$). At 2 years post-intervention, a follow-up analysis of the intervening 18 months was performed to establish whether the effect was sustained. The TAT for this 18-month period was 1.88±1.83 days, (95% CI=1.75–2.01, $p<0.0001$). For the entire 2-year post-intervention period, the TAT was 1.88±1.87 days (95% CI=1.78–1.99), a 49.7% reduction on the pre-intervention figure ($p<0.0001$).

In the 6 months pre-intervention, 219 PICC insertions were performed. In the initial 6 months post-intervention 421 PICCs were inserted. A total of 1,190 PICC insertions were performed in the entire 2-year post-intervention analysis period, a 35.8% increase on the expected level of activity extrapolating from the pre-intervention figures. This was achieved despite a 13.8% increase in interventional radiology (non-PICC) activity over the study period.

The average procedure time was 30 minutes and did not vary between the pre- and post-intervention periods. Procedure time did not exceed 1 hour on any occasion. The reductions achieved in the TAT were attributable to improvements in patient referral, scheduling, and transport rather than in procedure time.

There were no significant differences in patient demographics in the pre- (mean age 54.6 years, 47% female) and post- (mean age 57.9 years, 42.7% female) intervention cohorts.

The infectious diseases service was the single biggest referrer for PICC insertion, accounting for 23.6% of cases. Haematology/oncology accounted for 21.2% and general/colorectal surgery for 17.8%, with other specialties combined being responsible for 37.4%.

Discussion

The results of this study show a significant sustained improvement in overall numbers of PICC lines placed and in mean TAT despite a 13.8% increase in interventional radiology activity overall. This was achieved without the utilisation of any additional resources, and illustrates how existing capacity can be harnessed more efficiently.

The efficiency of many processes in radiology depends upon uninterrupted patient flow and minimisation in the occurrence and duration of periods that resources are not being utilised. This makes tools such as Lean Six Sigma extremely applicable. The dissection of a particular complex workflow process into its component parts can identify and eliminate non-valuable activities. This study is an example of the application of Lean Six Sigma to an isolated problem within a radiology department. The future of such thinking within healthcare, in general, will likely depend on its

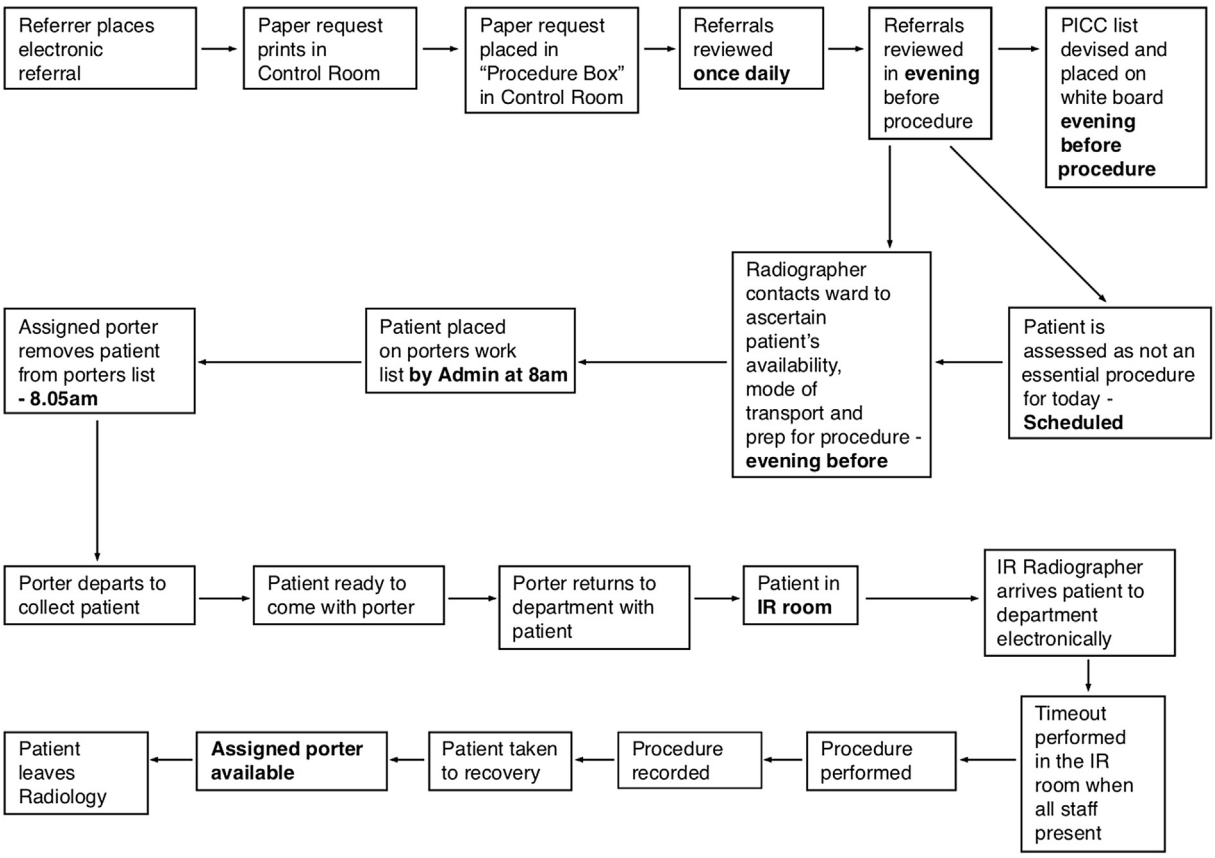

Figure 2 Rationalised stream map for the PICC insertion process following application of Lean Six Sigma methodology. Unnecessary steps were eliminated. Additional changes are highlighted in bold.

Table 1
Unnecessary steps that cause delay in the workflow process (specific actions taken to eliminate these in brackets where relevant).

- Multiple daily reviews of PICC referrals (single review of outstanding referrals each evening)
- Clinical teams presenting and discussing paper-based referral forms (electronic referral introduced)
- Scheduling of the daily list each morning (scheduled on the evening before instead)
- Radiographer requesting patient transport on the morning of the procedure (transport scheduled on the evening prior to procedure)
- Porter makes unnecessary journey to the ward when patient not present on ward or not prepared for procedure
- Communication to ward staff to advise on patient preparation when patient not available for procedure
- Communication to clinical team to advise on patient preparation when patient not ready for procedure
- Underutilisation of the IR room when patient not available for PICC insertion resulting in postponement or cancellation of other cases
- Radiographer contacting porter to ascertain why the patient was not available
- Radiographer locating IR registrar/consultant to perform procedure upon patient arrival in IR room (regular scheduled procedure start time introduced each morning)
- Radiographer contacting the patient's ward to arrange transport post-procedure (porters prioritise patients for return to ward following PICC insertion)
- Handover between IR procedure and IR recovery nurse (patients transferred directly back to ward bypassing IR recovery suite)

IR, interventional radiology; PICC, peripherally inserted central catheter.

adoption and incorporation into the culture and work practices of entire departments and institutions.

In terms of radiology in particular, the authors would argue that principles such as Lean Six Sigma are best applied at the level of complex multistep processes. Historically, medical practitioners have been encouraged to think of each patient interaction as unique, and given the heterogeneity within the spectrum of both diagnostic and interventional radiology, elements of an individual-centred approach should be retained. Nonetheless, the systems and processes around the delivery of individual procedures or interpretations are readily amenable to standardisation. Demand for PICC insertion is, like many patient care processes, highly variable. According to queuing theory, this makes "single-server systems," such as PICC insertion, vulnerable to being overwhelmed at times of peak referral.[8] Although variability in demand is unavoidable, minimisation of variability in delivery with regular scheduling and maximising the utilisation of capacity is essential.

The attractiveness of such strategies to managers and those with budgetary responsibilities in the area of healthcare is obvious. There is an inexorable trend towards increasing demand in modern medicine, with constant pressure to perform more examinations and interventions.[9] Ageing populations in most Western countries[10] and the additional demands associated mean that this is unlikely to change. Unfortunately, in most cases this must be achieved

with static or marginal increase in resources. The private industry origins of Lean Six Sigma mean an emphasis on eliminating non-useful activities to increase efficiencies without the need for additional resources. Inefficiency and error are widespread in healthcare[5] and opportunities for service improvement should therefore be plentiful.

The present study is subject to several possible limitations. The Hawthorne effect (a change in behaviour as a response to observation and assessment)[11] and productivity differences in staffing could be perceived as potential confounders. This would perhaps be valid in a shorter study; however, the significant, sustained effect achieved over a period of 2 years renders this null. As a high-volume centre, the present results may not necessarily be generalisable to institutions of different types. In addition, the impact of reduced TAT upon relevant hospital performance indicators, such as length of inpatient stay and contribution to expedited discharges, was not evaluated directly.

In summary, the application of Lean Six Sigma principles to the delivery of PICC insertion produced a significant improvement in the TAT from 3.74 days to 1.88 days. This effect was sustained over a 2-year interval without additional resources. The number of PICC insertions carried out increased by 35.8%.

Conflict of interest

The authors declare no conflict of interest.

References

1. de Koning H, Verver JP, van den Heuvel J, *et al*. Lean Six Sigma in healthcare. *J Health Qual* 2006;**28**:4–11. PMID: 16749293.
2. Karstoft J, Tarp L. Is Lean Management implementable in a department of radiology? *Insights Imaging* 2011;**2**(3):267–73. https://doi.org/10.1007/s13244-010-0044-5. PMID: 23099866.
3. Fairbanks CB. Using Six Sigma and lean methodologies to improve OR throughput. *AORN J* 2007;**86**(1):73–82. https://doi.org/10.1016/j.aorn.2007.06.011. PMID: 17621448.
4. Amaratunga T, Dobranowski J. Systematic review of the application of Lean and Six Sigma methodologies in radiology. *J Am Coll Radiol* 2016;**13**(9):1088–95. https://doi.org/10.1016/j.jacr.2016.02.033. PMID: 27209599.
5. Bahensky JA, Roe J, Bolton R. Lean Sigma—will it work for healthcare? *J Health Inf Manag* 2005;**19**:39–44. PMID: 15682675.
6. Bucci RV, Musitano A. A lean Six Sigma journey in radiology. *Radiol Manage* 2011;**33**(3):27–33. quiz 34-35. PMID: 21793459.
7. O'Brien C, Mc Marrow J, O'Dwyer E, *et al*. Peripherally inserted central catheters (PICCs) and potential cost savings and shortened bed stays in an acute hospital setting. *Ir Med J* 2018 Jan 10;**111**(1):670. PMID: 29869851.
8. White BA, Yun BJ, Lev MH, *et al*. Applying systems engineering reduces radiology transport cycle times in the emergency department. *West J Emerg Med* 2017;**18**(3):410–8. https://doi.org/10.5811/westjem.2016.12.32457. PMID: 28435492.
9. Chrysanthopoulou A, Kalogeropoulos A, Terzis G, *et al*. Trends and future needs in clinical radiology: insights from an academic medical center. *Health Policy* 2007;**80**:194–201. https://doi.org/10.1016/j.healthpol.2006.03.007. PMID: 16624441.
10. Lutz W1, Sanderson W, Scherbov S. The coming acceleration of global population ageing. *Nature* 2008 Feb 7;**451**(7179):716–9. https://doi.org/10.1038/nature06516. PMID: 18204438.
11. Sedgwick P, Greenwood N. Understanding the hawthorne effect. *BMJ* 2015;**351**:h4672. https://doi.org/10.1136/bmj.h4672. PMID: 26341898.