

BMJ Open Quality Novel solutions to old problems: improving the reliability of emergency equipment provision in critical care using accessible digital solutions

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ABSTRACT

Reliable provision of emergency equipment in Critical Care is key to ensure patient safety during medical emergencies and transfers. A problem was identified in incident reports and external inspections of processes that ensured the provision of such equipment for use by critical care teams in non-critical care areas in the form of grab bags. A comprehensive project was undertaken to tackle this including the provision of a bespoke digital system. Existing systems were reliant on staff remembering to check equipment and document checks on paper and there was no formal ability to hand over ongoing problems. A local project management approach, '7 Steps to Quality Improvement', which integrated many of the philosophies and tools from Healthcare Improvement was used. A bespoke digital system was designed and implemented with integrated improvements in equipment stocking ergonomics.

The reliability of documented equipment checks improved significantly, there was a significant reduction in the number of incident reports regarding emergency equipment and the time spent by staff doing equipment checks was reduced substantially with significant cost and resource improvements. This was so successful the format has been rapidly translated and spread to other areas such as operating theatres' difficult airway trolleys. Undertaking a structured quality improvement approach, using appropriate stakeholder engagement, digitalisation of systems and improvements in basic system ergonomics can have a substantial impact on the reliability and safety of emergency equipment provided for use by members of the critical care team.

PROBLEM

Musgrove Park Hospital (MPH) is a District General Hospital providing acute services for 340 000 people along with tertiary care for spinal and vascular emergency services.¹ The Critical Care unit has junior medical staff with turnover intervals between 3 and 6 months. The junior medical team provide safety checks of emergency equipment for the use in resuscitation and airway emergencies, both inside and outside of critical care.

In 2016, the Care Quality Commission (CQC) highlighted equipment checks as an area for improvement in Critical Care.² There

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ National standards exist for the provision of emergency equipment within critical care. There is no established practice or academic research as to how this should be achieved.

WHAT THIS STUDY ADDS

⇒ This report demonstrates that digital solutions can be used effectively to increase patient safety and reduce costs. It describes the digital system used and its advantages over a paper record over a 2-year period.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The authors believe this digital system could be used as a model for further implementation both locally for equipment outside of critical care and regionally to address similar issues with documentation.

was insufficient evidence of equipment safety checks for transfer bags, emergency drug pouches and airway trolleys. A daily handwritten, paper record of equipment checks was introduced in response.

A subsequent CQC inspection in 2020 highlighted the issue again. The report stated that, "the checking of the resuscitation equipment was not carried out consistently, as was the case on our previous inspection" despite these changes.¹ The paper documentation was inadequate and prone to error. Signatures were often illegible, and it was unclear when items of equipment had been replaced and why. Simultaneously, there were incidents of missing or excess equipment despite the documentation of checks. Despite the use of transfer bags that had undergone rigorous ergonomic design,³ there were concerns about the time and workload required to check them. In addition, the weight of the bags was implicated in a minor back injury sustained by a staff member carrying them to an emergency outside of the critical care unit.



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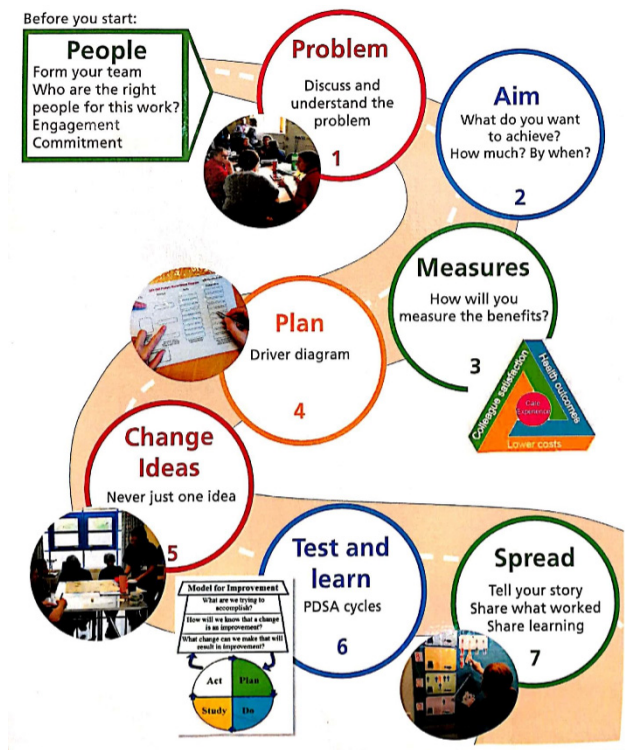


Figure 1 7 Steps to Quality Improvement': Somerset NHS Foundation Trust.

The national standard is that equipment should be checked daily against a standardised list and these checks documented. Used or expired equipment should be replaced and rechecked.⁴ An opportunity to reassess this process was undertaken as part of a Quality Improvement Fellowship starting in February 2020. Rigorous quality improvement methodologies were applied via a local project management structure: '7 Steps to Quality Improvement' (figure 1), grounded in healthcare leadership and improvement philosophies and methodologies.⁵

A multidisciplinary team bringing together senior sponsorship, local process understanding and knowledge of Quality Improvement theory was formed comprising the QI Fellow (Daniel Paul), an Acute Common Care Stem (ACCS) CT2 Trainee (Christopher Hunter), an Intensive Care Consultant and Department QI Lead (Ben Plumb) and two members of the Critical Care Outreach Team. An iterative approach to problem understanding, aim setting, measurement, project planning, divergent and convergent idea planning, iterative testing of change, spread and sustainability planning was undertaken.

We started by bringing together quantitative data and qualitative data (staff discussions and incident reports), and focused process evaluations (step 1).

A primary SMART (Specific, Measurable, Achievable, Relevant, and Time-Bound) aim was planned (step 2):

1. To improve the compliance of daily equipment checking (airway trolleys and transfer grab bags) to 90% within 6 months.

Secondary aims included:

1. To reduce the time taken to perform a routine check of the equipment by 90% within 3 months
2. To improve the reliability that transfer bags and airway trolleys contained all, and only, the equipment designated, to 100% in 3 months.
3. To reduce the weight of the transfer bags to below 13 kg

Background

National standards exist for the handling, availability and use of airway and emergency equipment within Critical Care and Transfer teams.⁴ The equipment must be available at any time. The Faculty of Intensive Care Medicine recommend that equipment such as transfer bags and airway trolleys should be standardised within a Critical Care department. The Fourth National Audit Project highlighted that a lack of immediately available equipment may prohibit management of a difficult airway and as a result may lead to adverse outcomes for patients.⁶

National standards recommend that this equipment should be checked and documented daily. There has been no identifiable work on the best methods to reliably check equipment or how this should be documented in Critical Care. Technology has been increasingly used to improve efficiency and reliability in stocking systems. This has recently been applied at MPH, with the operating theatres and critical care stock rooms moving to a digital stocking system.

Measurement

To understand the problem, a measurement plan was developed (step 3). Outcome measurement comprised the documentation of a completed daily check of two transfer bags, an out of areas drug pouch, two emergency intubation drug boxes and two Critical Care airway trolleys. Retrospective data were available from 23 January 2020, but these were then significantly disrupted by the first wave of the SARS-CoV-2 pandemic; with high compliance rates during the weeks prior to wave 1, a time of preparation, and then significant falls during times of system stress during waves 1 and 2. The baseline data prior to wave 1 were purely of compliance to documented checks, which from the number of incident reports being generated were not ensuring adequate checks of equipment.

Baseline process measurements included time to complete checks (baseline: mean 43 min per transfer bag), weight of transfer bags (baseline: 15 kg), numbers of incident reports (three in 2-month period 01–02/2021), and qualitative feedback from staff involved in using and checking the equipment; "Bag very heavy", "end tidal CO₂ battery running low and lasted only 15 minutes", "there were several items missing" and "several items which were out of date".

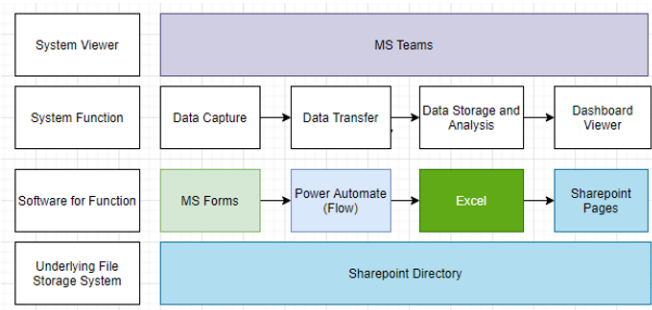


Figure 2 Digital system components.

Design

Junior doctors were frequently not familiar with the range of equipment or how to check individual items and expertise with the processes and documentation involved must not be assumed. Junior medical staffing comprises rotational staff with a heterogeneous mix of varying experience and backgrounds, including some with little experience in advanced airway management. Any process intended to improve standards in this area would need to be simple and easy to follow without requiring expert knowledge.

A series of interventions was planned using tools including driver diagrams, process mapping (step 4), and methods of divergent and convergent planning (step 5). The SEIPS (Safety Engineering Initiative for Patient Safety) 2.0 model was used to ensure consideration of the different aspects of the system.⁷

The interventions planned included:

- ▶ The provision of safety tags for the sealing of equipment that had been checked.
- ▶ An improved paper solution that better aligned with the equipment required to be checked and enabled issue handover was temporarily incorporated prior to the digital solution.
- ▶ Redesign of the contents of equipment bags and trolleys using stakeholder engagement.
- ▶ Ergonomic cognitive aids for checking and use of equipment, such as colour-coded checklists that included equipment stock room codes to attempt to prevent mis-stocking.
- ▶ A digital system using branching forms to guide staff through routine checks.
- ▶ Additional requirements for checks after use and monthly checks with checks of all equipment expiry dates.
- ▶ A digital dashboard presenting the status of equipment checking and project outcome data.
- ▶ Designed ‘nudges’⁸ in the daily handover cognitive aids to ensure recent checking compliance was reviewed.
- ▶ Training of several staff members in the technical support requirements and ability to iteratively change the system in the future

- ▶ Provision of comprehensive technical manuals for both daily users and those who wish to adjust or extend the system.

MPH, as part of Somerset Foundation Trust, invested in the Microsoft 365 platform as part of a Trust-Wide response to the COVID-19 pandemic during 2020–2021, with adoption of the platform throughout the trust. The 365 platform, including MS Teams, was accessible via any device and used trust login details for security. Information governance ensured that patient-identifiable information was not available via this platform and was not captured at any stage.

A multistep programme for entry, storage, analysis and visualisation of data was created (figure 2). A branching webform, based on process mapping, was created with Microsoft Forms. This was linked via Power Automate to an Excel document hosted on SharePoint to enable real-time data capture. This enabled accessible, but secure, data storage and compliance with information governance requirements.

Data entry was possible from any device, including personal devices. Each entry creates an audit trail. Forms cannot be retrospectively altered. The raw data are then automatically processed using Excel formulas, tables and charts, and then viewed in MS Teams via a SharePoint Page displaying automated dashboard outputs.

The webform (figure 3) contains instructions for safely checking an equipment bag. Ergonomic design principles including phraseology, text sizing, stock codes and colour were incorporated at all stages. A QR code linking the webform address was generated, then laminated and attached directly to each of the transfer bags and airway trolleys.

Strategy

Key strategies were:

- ▶ Rigorous ergonomic design.
- ▶ Comprehensive stakeholder engagement to ensure understanding of ‘work-as-done’ as accurately as possible.⁹
- ▶ A focus on sustainability and spread of improvements to other areas as appropriate.

Iterative development methodologies were undertaken using PDSA cycles (step 6) and the Institute for Healthcare Improvement’s Model for Improvement:

PDSA1: 01/03/2021

Plan: Updated existing paper-based documentation system

Do: Easily visible clipboard with prepopulated proformas for documentation of checks and any issues rectified or outstanding.

Study: Improvements in checking but still issues with illegibility, checking compliance and handover of issues.

Act: Move to digital format.

PDSA2: 01/03/2021

Plan: Add security tags to seal bag components

Do: Apply security tags (available as already on trust resuscitation trolleys).

11
Is the main door tag sealed?

Yes, I have left it sealed.

No, it was unsealed when I found it.

Yes, but this is a monthly check so I have broken it and will reseal at the end.

12
Does the top drawer contain the following items *

Location	Quantity	Item	Shelf Code
Top Drawer - Plan A	1	Mac 3	K030
	1	Mac 4	K030
	1	Side Stream CO2 (Filterline H Set)	I070
	2 of each	Endotracheal tubes (6.0/6.5/7.0/7.5/8.0/8.5/9.0)	K020
	1	Yankauer Sucker	K070
	1	Syringe 20ml	B040
	1	Syringe 10ml	B040
	1	Catheter Mount	J070
	1	Scissors	D050
	6	Lubricating Gel	ITU Prep Room
	1	Swivel Elbow	J060

Yes, everything was correct.

No, something was wrong but corrected.

Other

Figure 3 Example of part of a form for checking an airway trolley.

Study: Marked improvements in time for routine checks (40 min to 1 min) and substantial improvements in checking times for checks after use. However, there were initial issues maintaining stock of the tags.

Act: Added as a routine stock item to Critical Care stores.
PDSA3: 13/03/2021

Plan: Digital checking system using existing equipment stocklists.

Do: MS Form with QR codes, automated to Excel data sheet

Study: Improvements immediately in documentation compliance. Errors in stocking (spot checks undertaken) remained high due to issues with the equipment stocking lists not matching stores.

Act: Stakeholder-based redesign of equipment stocking lists.

PDSA4: 02/03/2021

Plan: Redesign stocking of transfer bags

Do: Stakeholder engagement to understand where redundancy and duplication are required in systems. Use of colour and stocking codes to improve accuracy.

Study: High levels of accuracy of stocking on spot checks. Weight reduction of transfer bags by 1.5 kg.

Act: Stakeholder engagement highlighted potential excessive equipment provision of the blue transfer bags for attending emergency calls where resuscitation trolleys are present (ie, ward environments). Potential for smaller bag for routine emergency.

PDSA5: 03 to 04/2021

Plan: Development of the digital forms from staff feedback.

Do: Iterative updates

Study: Improvements in form completion and feedback from staff

Act: Improve phraseology and clarity in branching design.
PDSA6: 30/04/2021

Plan: Spread digital system to the airway trolleys and intubation drug boxes.

Do: Design of checking stock lists for airway trolleys

Study: Substantial improvements in compliance and accuracy of stocking. Overchecking now occurring due to fragmented team and problems in communicating that equipment has already been checked.

Act: Look to sustain improvements made and reduce over checking.

PDSA7: 06 to 07/2021

Plan: Automated dashboard to feedback current checking status.

Do: Produce dashboard

Act: Use of SharePoint Pages via MS teams.

Study: Staff report improvements in ease of seeing when routine checks required. No current system for complete bag checks; if an error is inadvertently introduced into the system, it will potentially go missed and no ability to routinely check equipment and drug expiry.

PDSA8: 07 to 08/2021

Plan: Monthly checking system built in, including dashboard readout.

Do: Digital systems updated to enable monthly checking system

Study: Monthly checks now being undertaken but can be missed if dashboard not looked at.

Act: Improved communications to team, including senior medics, of need to check dashboard during morning handover and nudge monthly checks.

PDSA9: 06/2021

Plan: Smaller ergonomic 'red bag' for use for emergency calls to environments where a resuscitation trolley was present (ie, wards).

Do: Produce a lightweight backpack that provided advanced airway and breathing equipment but did not provide the additional critical care capabilities of the 'blue' transfer bags (such as intravenous access, arterial monitoring and suction).

Study: Qualitative feedback from staff highly appreciative of the lighter weight bag with less duplication.

Act: Signposting on the bag itself for how to rapidly get advanced equipment, that is, blue bag or transfer trolley (monitoring, pumps, ventilator) from ICU to the environment needed.

PDSA10: 08 to 10/2021

Plan: review sustainability of interventions after Fellow position ends

Do: Materials for induction of new staff in August rotation including user guide. Training of local staff in digital system to enable spread to other areas and ability to update system as required. Technical manual produced.

Study: Improvements sustained; technical issues able to be updated by staff trained in system.

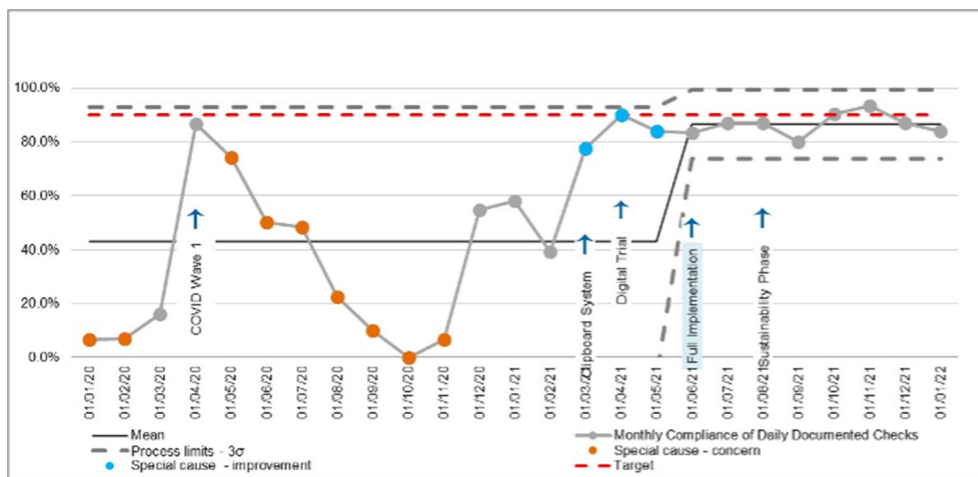


Figure 4 SPC chart for documented checks of airway trolley 1 - starting 01/01/20.

Act: Monitor sustainability (critical care to move to new environment in a couple of years' time—system design likely to need overhaul at this stage) and look to spread intervention design to other appropriate areas. Look to train further staff in system.

RESULTS

Transcribing the paper records from the previous year was a time-consuming and laborious task; however, following the digital intervention, the data were much easier to tabulate with a minimal risk of error. This allowed a move from retrospective data capture to continuous data metric availability. Initially visualised as run charts, these were later detailed enough to allow the production of SPC charts. SPC charts (figures 4–8) were created using tools publicly provided by the NHS Improvement *Making Data Count* Initiative.¹⁰

Producing data in a time series format enabled a joint analysis of quantitative data with qualitative data to improve understanding of the system. Understanding of the level of common cause variation that the interventions aimed to improve could be more clearly seen and

special cause variations (such as caused by the disruptions of the pandemic) could easily be seen and interpreted. While improvements were seen in the reliability of both the transfer bags and airway trolley checks, neither was seen to reach 100% (figures 4–8). All the areas checked include critical resuscitation equipment, which presents a potential patient safety risk if not kept up to standard.

This intervention was carried out during the COVID-19 pandemic. As can be seen in the statistical process control (SPC) charts for the primary outcome (figures 4–8), special case variations occurred with each wave prior to the introduction of the digital interventions (March 2021).

Process improvements were seen in:

- ▶ Efficiency: Times to complete checks (baseline mean 43 min).
- ▶ Ergonomics: 10% weight reduction of blue transfer bags via removal of excess stock and optimisation of contents list (baseline 15 kg), addition of 'red' transfer bag with weight of 3.2 kg, for standard 'ward responses' to reduce duplication with cardiac arrest trolley.

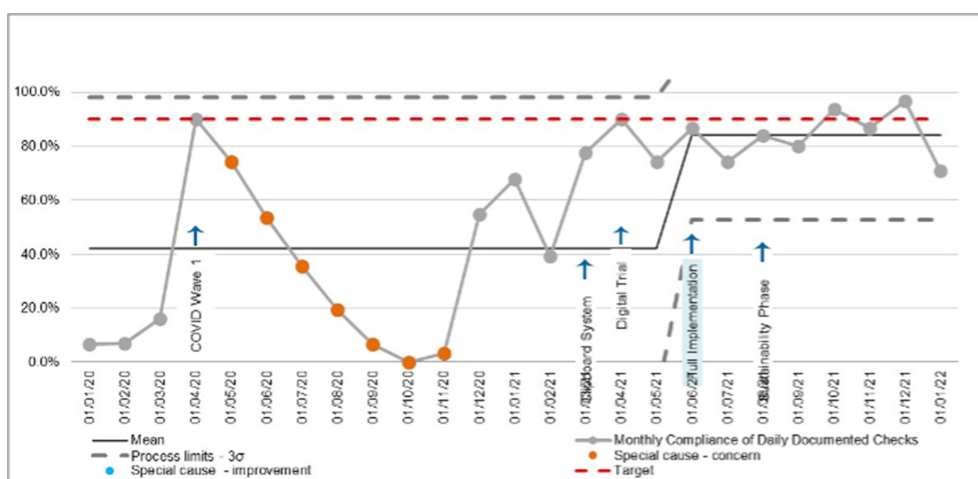


Figure 5 SPC chart for documented checks of airway trolley 2 - starting 01/01/20.

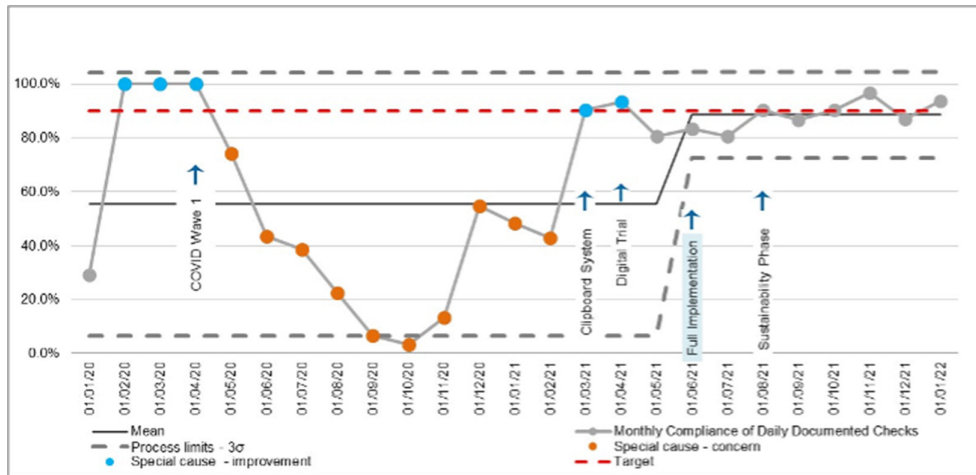


Figure 6 SPC chart for documented checks of blue transfer bag 1 - starting 01/01/20.

- ▶ Safety: Numbers of incident reports regarding emergency equipment (three in 2-month period 01–02/2021), reduced to none in the next year.
- ▶ Staff satisfaction: Very positive qualitative survey feedback from staff involved in using the equipment and checking it.

While the interventions have improved efficiency (time for checks), safety (reliability of stocking, as seen in a reduction in incident reporting) and improvement in documentation compliance, they have not been absolute. This may be driven by organisational issues such as competing workloads and the impact of rotational staff. Although as the system has become established, this has reduced common cause variation such as staff forgetting as more permanent staff are familiar. Additional resources such as information for new staff at induction were produced and integrated into existing resources.

Before the introduction of a dashboard, there was an initial duplication of work. Introducing a dashboard allowed staff to see when equipment was last checked, completely stopped duplication, and continued to improve documentation compliance and reduce common cause variation.

Balancing measures included monitoring for new safety issues due to the changes, of which none have been raised at any stage, and the cost of implementing the system. An investment of approximately 160 hours of QI fellow time, 20 hours of CT2 time, 4 hours of Band 6 nursing, 2 hours of Band 4 clerical time, 4 hours of consultant time, a new portable end-tidal CO₂ monitor and a small volume of stationary material were required with an approximate initial cost of £5000.

Potential cost savings can be approximated. While it is impossible to extrapolate the potential cost savings in the indirect improvements in patient care, some conservative estimates of saving of staff time can be undertaken. Conservatively 45 min of junior doctor time has been saved every time a check is undertaken.

Accounting for the requirement for monthly full checks, 266 hours and 15 min of junior doctor time has been saved each year. These checks are most frequently undertaken by a CT1–2 grade doctor and a yearly saving of £5050.76 of staff time is conservatively estimated.¹¹

Any savings in patient health or safety outcomes, wasted duplicated equipment or potential injury to staff are not accounted for but would be in addition to this. Thus,

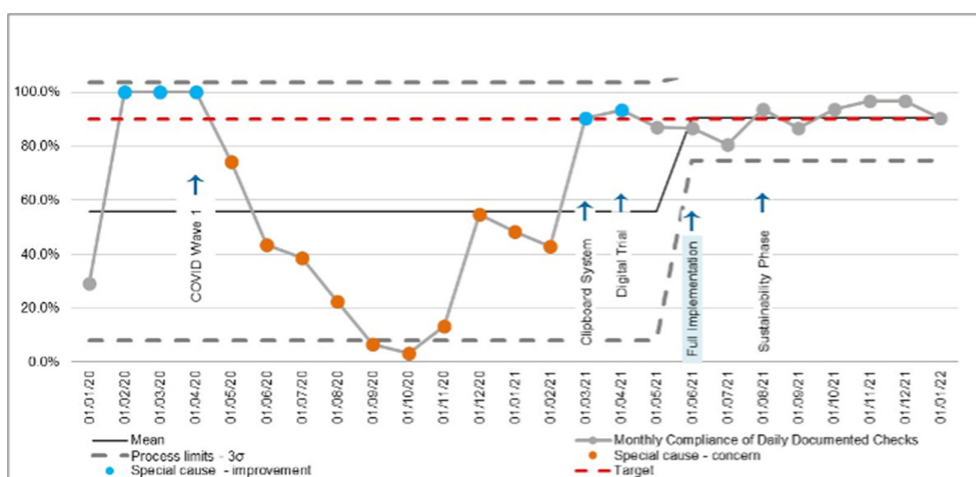


Figure 7 SPC chart for documented checks of blue transfer bag 2 - starting 01/01/20.

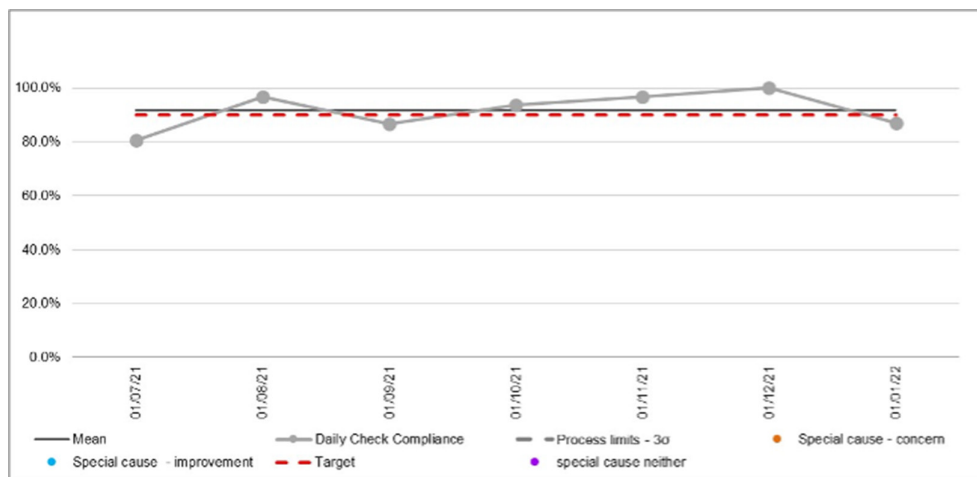


Figure 8 SPC chart of documented daily checks of red transfer bag (created 06/21) - starting 01/07/21.

initial costs have been met well within the first 12 months and will produce ongoing yearly savings of more than £5000.

Lessons and limitations

The attention paid to the transfer bag and airway trolley checks throughout the duration of this project by members of the department will have increased awareness temporarily. However, high levels of checking compliance have now been maintained for 6 months following the project entering a sustainability phase.

The use of QR codes and an ergonomically designed digital solution allowed illustrated instructions to be delivered where needed. This includes how to check and how to replace equipment. This improved both the competence and the confidence of junior staff members who may not have been familiar with the environment, equipment, or the checking process.

There is occasional variation in checking between the high-dependency unit (HDU) equipment compared with the intensive care unit (ICU) equipment. There may have been geographical factors (location of the trolley relative to areas of acuity) or personnel (often more junior staff work on HDU than ICU) that impact on this.

Local investment in trust-wide digital licenses for MS Office packages, via a secured and governed login system, meant there was no additional cost to the project outside of printing and laminating the QR codes and cognitive aids, except the time investment of staff involved.

The use of such software solutions enabled the solution to be built with no investment from local Information Technology or Digital teams. However, if the software had not been implemented previously, then this would represent a financial cost. Open-source alternatives are available, but the authors cannot speak to their effectiveness in comparison with the programmes used or the governance implications of using software not accessed through appropriately secured and authorised systems.

The effects of waves of the SARS-CoV-2 pandemic are clearly seen before a digital solution was implemented. Digital working became more commonplace during the

pandemic and the use of MS Teams potentially overcame barriers to digital solutions. However, the increased workload, sickness and stress associated with the pandemic may have produced barriers to improvement work. Formal and informal qualitative feedback suggested that staff were receptive to this intervention as it was specifically aimed at improving the reliability, safety, and efficiency of their work with improvements readily seen and fed back to them.

CONCLUSION

Switching to an ergonomically designed and digital solution for equipment checking has improved reliability, safety, efficiency and usability, and has been cost saving. The use of a local project management tool ('7 Steps') combined with the synergistic use of Quality Improvement and Human Factors and Ergonomics methods and tools enabled a rigorous approach to problem solving. The impact has been sustainable improvement that has rapidly spread to other areas.

The formation of a multidisciplinary project team combined with high levels of stakeholder engagement enabled the problem to be thoroughly understood. The use of co-ordinated quantitative and qualitative metrics enabled rapid iterative development during a time of system strain due to a global pandemic.

Ergonomically designed interventions have improved the efficiency and safety of the system with reductions in staff workloads and positive qualitative feedback. This has been sustained despite large turnovers in staff. An additional airway trolley has subsequently been added; we have been able to 'bolt-on' further QR codes and data rows to our dashboard to easily expand the data checking process as required.

The digital components are built from readily available software and required minimal background understanding with any advanced techniques self-taught. However, the self-built system could be vulnerable to future updates affecting compatibility between systems and there is no specific support from internal



or external information technology teams for this system. A comprehensive explanation of the system and technical support manual was created, and several local staff trained to provide sustainable support.

Electronic equipment checks could be applied to any area of equipment checking by clinical staff. Ergonomic and electronic solutions, as inspired by this project, could also be translated into other departments and areas where frequent checks of critical equipment are required, ultimately improving reliability, safety and quality. A potential area for future spread of this intervention would be to resuscitation trolleys but would require a whole hospital approach due to the existing standardised nature of their provision. In the year since implementation, this solution has been used as a model for use with theatre difficult airway equipment and regional block equipment by other members of the anaesthetic department.

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