Institution: University of Oxford		
Unit of Assessment: 1 – Clinical Medicine		
Title of case study: Electronic systems to improve safety and effectiveness of blood transfusion		
Period when the underpinning research was undertaken: 2003 - 2019		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Mike Murphy	Consultant Haematologist (NHS Blood and Transplant), and Professor of Transfusion Medicine (University of Oxford, Honorary)	1996 – present (Cat C)
Julie Staves	Transfusion Laboratory Manager (OUH NHS)	2001 – present (Cat C)
Period when the claimed impact occurred: Aug 2013 – Oct 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

University of Oxford researchers developed a unique electronic (paperless) process for blood ordering, blood sample collection from patients, and issuing of blood in hospital laboratories and distribution to patients for transfusion. This has improved patient safety by reducing the number of wrong transfusion events, resulted in more timely availability of blood for urgent transfusions, and saved money through efficiencies in staff time and appropriate blood use. The first hospital-wide implementation in Oxford hospitals resulted in a 26% reduction in blood costs (more than GBP1,000,000 per year) over the period 2013-2019. These electronic processes are now marketed worldwide by *Haemonetics* (Boston) and have been implemented in 435 hospitals in the NHS and worldwide. The research resulted in changes to national guidelines including NICE, clinical specialty and UK Blood Transfusion Services and produced specifications for the electronic transfusion process for the National Patient Safety Agency, and the Healthcare Safety Investigation Branch.

2. Underpinning research

Researchers at the University of Oxford developed and implemented a unique end-to-end electronic (paperless) transfusion process to improve the safety and efficiency of hospital transfusion. The process utilises barcoded patient wristbands, bedside handheld computers, electronically controlled blood fridges and is fully integrated with hospital laboratory information management systems.

Incorrect blood component transfusion is one of the most frequent serious transfusion incidents and errors responsible for these incidents frequently involve patient misidentification. University of Oxford researchers investigated the role of barcode technology in increasing the safety of blood transfusion in non-acute haematology settings finding that significant improvements were made in the correct blood sample collection and administration of blood [1]. Further work established feasibility and safer practice in an acute clinical area, cardiac surgery. It was then linked to an electronic system for blood collection and tracking to provide end-to-end electronic control and documentation of the complete hospital transfusion process [2]. Staff found the system easy to operate and preferred it to standard procedures.

The rapid provision of red blood cell (RBC) units to patients needing blood urgently is an important issue in transfusion medicine. This has been facilitated by the development of electronic issue of units of blood ("electronic crossmatch"). The Oxford team evaluated a system for electronic remote blood issue [3] developed as an enhancement to the electronic bedside system and found that it improved the median time to deliver urgently required RBC units to the

patient from 24 minutes to 59 seconds. The study also found that unused requests were reduced significantly from 42% to 20%, the number of RBC units issued reduced by 52%, the number of issued units that were transfused increased from 40% to 62%, and there was a significant reduction in the workload of blood bank and clinical staff. A later study across five centres in the UK and USA [4] confirmed these findings.

Oxford researchers showed the end-to-end electronic transfusion management system to be an excellent tool for monitoring hospital transfusion practice including compliance with national regulations for the traceability of every blood unit and national recommendations for the training and competency assessment of staff without the need for establishing additional procedures [5].

This research was funded by NHS Blood & Transplant; the Oxford University Hospitals (OUH) NHS Foundation Trust; the Haematology Theme of the NIHR Oxford Biomedical Research Centre (a collaboration between the University of Oxford and OUH NHS Foundation Trust); and Innovate UK.

3. References to the research (all journal articles)

1. Turner CL, Casbard A & **Murphy MF**. Barcode technology: its role in increasing the safety of transfusion. *Transfusion* 2003:43:1200-9. DOI: 10.1046/j.1537-2995.2003.00428.x
2. Davies A, **Staves J**, Kay J, Casbard A & **Murphy MF**. End-to-end electronic control of the hospital transfusion process to increase the safety of blood transfusion: strengths and weaknesses. *Transfusion* 2006:46:352-64 DOI: 10.1111/j.1537-2995.2006.00729.x
3. **Staves J**, Davies A, Kay J, Pearson O, Johnson T & **Murphy MF**. Electronic remote blood issue: a combination of remote blood issue with a system for end-to-end electronic control of transfusion to provide a "total solution" for a safe and timely hospital blood transfusion service. *Transfusion* 2008:48:415-24. DOI: 10.1111/j.1537-2995.2007.01545.x
4. Staples S, **Staves J**, Davies J, Polley N, Boyd JS, Lukas M, Popovsky MA, Frank SM, Ness PM, **Murphy MF**. Electronic remote blood issue supports efficient and timely supply of blood and cost reduction: evidence from five hospitals at different stages of implementation. *Transfusion* 2019:59:1683-91. DOI: 10.1111/trf.15231
5. **Murphy MF**, Fraser E, Miles D, Noel S, **Staves J**, Cripps B, Kay J. How do we monitor hospital transfusion practice using an end-to-end electronic transfusion management system? *Transfusion* 2012:52:2502-12. DOI: 10.1111/j.1537-2995.2011.03509.x

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4. Details of the impact

Pathway to Impact and Context

The 'end-to-end' electronic transfusion process was implemented initially in all acute hospitals in Oxfordshire prior to 2013. Benefits described below have been realised from 2013 to 2020, quantified by follow-up studies from the Oxford team. The team has long supported adoption in other settings, for example specification for an electronic process for transfusion was developed for the National Patient Safety Agency as early as 2006, and engagement with national schemes such as Serious Hazards of Transfusion (SHOT). Through this engagement and the dissemination of the primary research and follow up studies, the take-up of these processes has been recommended in national guidelines from 2015 onwards. The Oxford team also developed a long-standing collaboration with Haemonetics Ltd (Boston), enabling incorporation of research findings into Haemonetics' commercially available software and products, including the BloodTrack® system, which are now marketed internationally.

Benefits to Clinical Practice

The development of a process for electronic blood product ordering with an integrated clinical decision support system (CDSS) allows collection of data regarding the patient's clinical

condition and the justification for the blood product order. An alert is generated in real time if the order is outside agreed guidelines. Feedback is provided to clinicians in several ways including contact with the prescribing clinician if an alert is generated, to ask for further information and if necessary, provide education; an online dashboard allowing all clinicians to visualise their blood ordering practice; a summary report circulated on a quarterly basis to senior clinical staff for cascade to their teams; and monthly review meetings with the junior haematology doctors. These processes have multiple benefits:

Improvements to Patient Care and Safety: A study with Serious Hazards of Transfusion (SHOT) analysed data from 57 wrong component transfused (WCT) events from approximately 2,000,000 blood component transfusions administered in the UK in 2015 and 2016 and showed that patient safety has been improved by reduced wrong transfusion events and avoidance of unnecessary transfusion. In cases that related to sample labelling, blood collection and administration, no WCTs occurred with sampling or administration using electronic processes, whereas 17 WCTs occurred with manual processes [A(i)].

Improvements in compliance with good practice. Local data has found much greater compliance with correct procedures and fewer errors [1,2,5]. Murphy and colleagues found that significant improvements were made following the introduction of the electronic system, including a rise from 8% to 100% in checking that the blood group and unit number on the blood pack matched the compatibility label and the pack was in date ($p \leq 0.0001$). Similar significant improvements were found in blood sample collection, the collection of blood from blood refrigerators, and the documentation of transfusion. Improved compliance with guidelines for transfusion and avoidance of unnecessary transfusion following the implementation of electronic blood ordering; for example, in the haematology ward in an Oxford hospital, compliance with RBC transfusion guidelines increased from 74% in 2014 to 95% in 2019 [A(ii)].

Improvements In Staff Time and Efficiency. The Oxford team also found that staff found the system easy to operate and preferred it to standard procedures [2]. The process involves one nurse rather than two, and there is a 50% reduction in the time for a nurse to undertake pre-transfusion patient/blood identification at the bedside [1]. The speed of delivery of blood for urgent transfusions through electronic remote blood issue has also been increased [3,6]. The electronic remote issue process avoids the need for multiple blood transfusion laboratories in centres with several hospitals as blood can be provided safely for urgent cases at remote sites. This has meant that the transfusion service in Oxfordshire operates from a central laboratory at the John Radcliffe with satellites at the Churchill and Horton Hospitals rather than with 3-4 stand-alone blood transfusion laboratories.

National and International Guidance

In the ***NICE guideline on blood transfusion*** (2015) using an electronic patient identification system when undertaking blood transfusion is recommended in the guideline [B] largely based on the Oxford research [5]. The research was also endorsed nationally as an NHS QIPP (Quality, Innovation, Productivity and Prevention) case study in 2016, entitiled: "*Electronic blood transfusion: improving safety and efficiency of transfusion systems"* [C].

The **British Society for Haematology guidelines** on the administration of blood components (2017) state that *"…Electronic patient ID: Electronic systems are available to help improve patient ID procedures…"* and *"the systems employed must be robustly designed and implemented to ensure that patient safety is enhanced"* [D], in both cases citing [5].

The research provided the evidence for a recommendation in the 2017 **Annual Report of the Serious Hazards of Transfusion (SHOT) scheme** [E]:

> "*All available information technology (IT) systems to support transfusion practice should be considered and these systems implemented to their full functionality. Electronic blood management systems should be considered in all clinical settings where transfusion takes place. This is no longer an innovative approach to safe transfusion practice, it is the standard that all should aim for. Action: Hospital Chief Executives, Hospital Risk Managers and Hospital Transfusion Teams."* [E].

The Medical Director for SHOT confirmed in October 2020,

> "*The use of barcode scanning technology…has proved to be a simple but effective way to reduce errors at the point of sample collection. Professor Murphy's seminal studies on this practical solution…were highly successful at his home institution at Oxford. The resulting publications demonstrating a clear safety benefit to patients has helped to stimulate the adoption of electronic patient identification in the UK and internationally. This was one of the key SHOT recommendations in 2017 and SHOT continue to stress the importance of incorporating electronic blood management in all clinical settings where transfusion takes place*." [L(ii)]

Professor Murphy provided information, advice and guidance to the **Healthcare Safety Investigation Branch (HSIB)** during their 2019 investigation into solutions to prevent wrongly labelled blood samples [F]. In its report entitled "*Wrong Patient Details On Blood Sample - Healthcare Safety Investigation I2019/003*" the HSIB Recommendation 2019/46 was that *" … NHSX should take steps to ensure the adoption and ongoing use of electronic systems for identification, blood sample collection and labelling".*

Internationally, the 2016 haemovigilance report from Australia's National Blood Authority highlighted the importance of technology, including portable barcode readers and/or radio-frequency identification scanners, to reduce transfusion process-related errors, and the value of decision support tools to improve clinical prescribing, based on the Oxford research [G,L(iii)].

Cost savings in the NHS

The Chief Medical Officer, in her 2014/*2015 NIHR Annual Report*, highlighted the savings resulting from the system:

> *"... a new blood management system trialled and tested by our Oxford NIHR Biomedical Research Centre saved Oxford University NHS trust half a million pounds* [GBP500,000] *last year. It uses barcode patient identification syste guaranteeing each and every patient recieveds the right blood in the right amount. This system, if implemented across the NHS could create savings of more that £50m* [GBP50,000,000] *each year and is a fool-proof way of ensuring patients' safety."* [H]

Longer-term analysis showed the first hospital-wide implementation of electronic blood ordering and decision support in Oxford hospitals resulted in a 26% reduction (USD1,340,000; GBP1,000,000 per year) in blood costs over the period 2013-2019 [A(ii)].

National and international implementation

A survey of UK hospitals participating in SHOT published in 2019 found that over 50% of UK hospitals were using an electronic system for the bedside transfusion process and/or blood collection from blood refrigerators. [A(i)]. The NHS Blood and Transport 2018 national comparative audit of blood transfusion demonstrated a widespread adoption of the remote blood allocation systems, with 67.5% of hospital now utilising these [I].

The Co-Director of the Massachusetts General Hospital confirmed that "*As a direct consequence of the work at Oxford, my hospital began in 2012 to develop a similar system for patient identification and safe transfusion"* [L(i)]. A recently reported study [J] shows a step-change in compliance with basic patient identification in theatre at the time of transfusion upon its implementation in 2014. Adoption has also been confirmed in Toronto [L(i)] and a leading Australian hospital [L(iii)].

As at October 2020, the *Haemonetics* BloodTrack® system has been implemented in the NHS in [text removed for publication]; in Ireland in [text removed for publication]; and in many other countries including in the United States, where it is used in [text removed for publication]. In Italy, where market entry commenced in 2018, it has been implemented in [text removed for publication] and during 2020 the software has been translated into French, Spanish and German [K]. The The Co-Director of the Massachusetts General Hospital corroborates that "*commercial systems such as Haemosafe® and Bloodtrack® have recently been introduced in an effort to reduce barriers to implementation. These commercial systems are fundamentally based on the original Oxford work.*" [L(i)]. The General Manager (Hospital, W. Europe) for Haemonetics

confirmed: "*It's quite clear that the relationship we have enjoyed with yourself and the EBTS team in Oxford has had far reaching impact to transfusion safety very broadly in the UK and with increasing presence around the Globe.*" [K]

The Oxford team is continuing to work on enhancing the electronic transfusion process, and supporting other hospitals to implement it including further documentation of the clinical and economic benefits in the largest implementation to date at Barts Health (4 acute hospital sites serving 2,500,000 people in east London) [L(iv)].

5. Sources to corroborate the impact

A. Follow up studies (journal articles):
i) Murphy MF, Addison JJ, Poles D, Dhiman P, Bolton-Maggs P. Electronic identification systems reduce the number of wrong components transfused. *Transfusion*. 2019;59:3601-3607 DOI: 10.1111/trf.15537
ii) Staples S, Salisbury RA, King AJ, Polzella P, Bakhishli G, Staves J, Murphy MF, How do we use electronic clinical decision support and feedback to promote good transfusion practice. *Transfusion*. 2020:60:1658-1665. DOI: 10.1111/trf.15864

B. NICE guideline on blood transfusion (2015), available at https://www.nice.org.uk/guidance/ng24

C. Electronic blood transfusion: Improving safety and efficiency of transfusion systems Provided by: Oxford Radcliffe Hospitals Publication type: Quality and productivity example, 2016

D. The administration of blood components: a British Society for Haematology Guideline (2017) DOI: 10.1111/tme.12481

E. Annual Report of the Serious Hazards of Transfusion (SHOT) scheme. See page 17 https://www.shotuk.org/wp-content/uploads/myimages/SHOT-Report-2017-WEB-Final-v4-25-9-18.pdf Page 17.

F. Healthcare Safety Investigation Branch (HSIB) report "*Wrong Patient Details On Blood Sample - Healthcare Safety Investigation I2019/003*" (2019) https://www.hsib.org.uk/investigations-cases/wrong-patient-details-blood-sample/

G. 2016 Australian Haemovigilance Report, see recommendations 4 and 5 on page 10 https://www.blood.gov.au/system/files/Australian-Haemovigilance-Report-2016.pdf

H. NIHR annual report 2014/15

I. NHS Blood and transport, 2018 National Audit National Comparative Audit of Blood Transfusion. Audit of the Management of Major Haemorrhage. https://nhsbtdbe.blob.core.windows.net/umbraco-assets-corp/19130/2018-major-haemorrhage-audit-full-report.pdf

J. Vanneman, MW et al. Improving Transfusion Safety in the Operating Room With a Barcode Scanning System Designed Specifically for the Surgical Environment and Existing Electronic Medical Record Systems: An Interrupted Time Series Analysis, *Anesthesia & Analgesia*. 2020:131(4):1217-1227 DOI: 10.1213/ANE.000000000000508

K. Letter from General Manager – Hospital West Europe, Haemonetics, detailing usage of BloodTrack system in the UK and internationally.

L. Letters confirming the impact of the research on clinical practice in UK and internationally:
i) Co-Director, Blood Transfusion Services, Massachusetts General Hospital
ii) Medical Director, Serious Hazards of Transfusion (SHOT)
iii) Consultant Haematologist, Monash Health
iv) Consultant in Haemostasis and Transfusion Medicine, NHS Blood and Transplant and Barts Heath NHS Trust