Technoleg Iechyd Cymru
Health Technology Wales

Evidence Appraisal Report

Electronic blood management systems for blood transfusion

Executive summary

- We searched for evidence that could be used to answer the review question: What is the clinical and cost effectiveness of electronic blood management systems (EBMS) compared to standard methods of blood management? EBMS describes any electronic system used to check and/or verify identification of patients, blood samples, or blood units at any stage of the transfusion process.
- We identified ten studies comparing the effectiveness of EBMS to alternative blood tracking and verification processes during transfusions. The latter processes were not always well described, but those described in sufficient detail were all 'manual' processes, such as use of written documentation and verification of identification/samples by a second staff member. Two studies were multicentre comparisons of EBMS to manual processes; the remainder were single centre studies measuring outcomes before and after implementation of EBMS.
- There is some evidence to suggest that EBMS is associated with lower rates of incorrect transfusions, 'wrong blood in tube' errors, sample rejection and blood wastage. However, many of the studies did not report any statistical measures of effect sizes, and for some outcomes events rates are very low, meaning it is difficult to accurately quantify the possible benefits of EBMS. Potential risks of bias within the included studies also reduce the certainty of the evidence.
- We identified very limited amounts of evidence on the effect of EBMS on procedure time: a single study measured a single aspect of the process and reported no time differences to alternative processes. We also searched for evidence on patient mortality due to transfusion errors, length of hospital stay and quality of life, but did not identify any evidence reporting the effect of EBMS on these outcomes.
- No health economic studies have been included in this evidence appraisal report.
- We developed a cost analysis, from the Welsh NHS perspective, comparing electronic blood management systems with a paper-based system, based on estimates of staff resource use to which the unit costs staff time were applied. The base case results of the cost analysis demonstrate that EBMS saves £0.32 per person in the first year and £19.93 per person in each subsequent year compared with a paper-based system. The results are sensitive to changes in the population size and in staff time using EBMS.

1. Purpose of the evidence appraisal report

This report aims to identify and summarise evidence that addresses the following question: What is the clinical and cost-effectiveness of electronic blood management systems (EBMS) compared to standard methods of blood management?

Evidence Appraisal Reports are based on rapid systematic literature searches, with the aim of identifying the best clinical and economic evidence on health technologies. Researchers critically evaluate this evidence. The draft Evidence Appraisal Report is reviewed by experts and by Health Technology Wales multidisciplinary advisory groups before publication.

2. Health problem

Blood transfusion is a process whereby blood components (red blood cells, white blood cells, plasma, clotting factors, or platelets) are transferred intravenously to a patient. Whilst the term transfusion can be used to refer solely to the administration of blood, the process involves a number of prior procedures:

- A clinical decision is made to transfuse
- The patient receives information about the transfusion and provides consent
- Blood components are requested/ordered
- A blood sample is taken from the patient for pre-transfusion testing (most commonly to determine blood type and ensure compatible blood is ordered)
- Collection of blood components from storage and delivery to the clinical area where transfusion will take place.

During and after blood component administration, the patient will be monitored, and after completion, the transfusion is documented in the patient's records along with any reactions to the transfusion (Robinson et al. 2018).

During requesting, blood sampling, collection and administration, errors can result in misidentification of a patient, their blood sample, or the blood component intended for them. If undetected, such errors pose significant risks to patients and in cases where blood is incompatible with a patient's blood type, can result in severe, sometime fatal, adverse reactions (Hill & Derbyshire 2021, Robinson et al. 2018). In the UK, Serious Hazards of Transfusion (SHOT) collects information on transfusion reactions, adverse events, and also error incidents (whether or not these resulted in patient harm) during the transfusion process. In 2020, there were 323 reported incidents in the UK where the incorrect blood component was transfused (SHOT 2021). Transfusion requires reliable and robust processes to be in place to minimise and, where possible, eliminate such errors.

3. Health technology

Patient identification, and the verification of samples and blood components from/intended for the right patient, has traditionally used manual and written checks. An example of such processes would be two nurses independently checking written documentation and the patient's identity at the bedside before beginning a transfusion. Manual checks for patient identification may include cross-checking a patient's details by asking them to state predetermined details such as their name and date of birth, and cross-checking these against details attached to the blood component to be transfused. Alternatively these details may be read off a patient's wristband and cross-checked against the labelled blood component. Some processes add the

use of distinctive identifying numbers or labels affixed to a patient's wristband at the time of pretransfusion checking, which must be matched to the same label on the blood component (Wood et al. 2017).

Electronic systems provide an alternative method of checks to identify patients and blood during the transfusion process. The details vary according to the systems used, but typically involve use of a unique electronic identifier (barcode or radio-frequency identification (RFID) tag) that is associated with each transfusion and used to identify and match a patient with the correct sample and blood component. Electronic identification can be used at a single step in the process – most commonly to verify the identity of the patient and match it to the correct blood component before transfusion – or can cover multiple steps, up to 'vein-to-vein' systems that cover sampling, blood collection and blood administration. Commercial systems exist and also systems developed in-house by hospitals or other healthcare providers. We are unaware of any standards to classify such systems; in this report, we use the term 'electronic blood management systems' to described any electronic system used to check and/or verify identification of patients, blood samples, or blood units at any stage of the transfusion process (SHOT 2021, Wood et al. 2017).

BloodTrack (Haemonetics) is an EBMS consisting of a suite of software products that can be used independently or together. The software available can be used during blood component storage and collection, with electronic verification during collection, for ward-based transfusions (BloodTrack Courier), or when blood is required more urgently in emergency/trauma settings (BloodTrack Emerge) or surgery/intensive care (BloodTrack OnDemand). The BloodTrack Tx module can be used for transfusion verification immediately prior to and during a transfusion, to carry out checks that the correct blood component is transfused and to record patient vital signs and any transfusion reactions. The SafeTrace Tx software modules can also be used to centrally manage blood product inventory, ordering and transfusion activity (Haemonetics 2017).

3.1 Existing recommendations

The 2017 SHOT Annual Report included the following Key Recommendation:

"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." (SHOT 2018)

A 2019 Investigation by the Healthcare Safety Investigation Branch (HSIB) entitled *Wrong Patient Details On Blood Sample* made the following Safety Recommendation:

"It is recommended that NHS should take steps to ensure the adoption and ongoing use of electronic systems for identification, blood sample collection and labelling." (HSIB 2019)

4. Clinical effectiveness

4.1 Overview

We searched for and summarised evidence on the effectiveness of EBMS compared to other methods of blood management. Section 10 and Appendices 1 and 2 describe the methods used to search and screen the evidence. We identified 10 studies that reported relevant evidence. Six of the ten studies were reported by a previous evidence review conducted in 2015 as part of a NICE guideline (NICE 2015), which we adapted. Four of the ten studies were published after NICE's review and were identified by our literature search.

Table 1 details the design and characteristics of each included study. Eight studies used a before-and-after design, measuring outcomes following the introduction of EBMS and comparing them to retrospective outcomes with previous blood management systems from before the intervention was introduced. All of these studies took place at single centres. The two other studies used a comparative design, using either audit or survey data to compare outcomes across centres that used different types of blood management systems (either electronic or manual). The studies were conducted in the United States, Hong Kong, UK, Japan, Spain, Canada, New Zealand, Germany, Italy, and Taiwan. Three studies included data from UK centres or were conducted exclusively in the UK.

4.2 Outcomes

Table 2 and Sections 4.2.1 to 4.2.6 describe the evidence identified for each outcome of interest.

Table 1. Design and characteristics of included studies

Study reference	Methods, setting	Characteristics of samples/ participants	Intervention(s)	Outcomes	Follow-up period	Comments
Studies included within NICE Guideline NG24						
Askeland et al. (2008)	Study design: Before and after study Setting: United States, single centre Study period: 2003 to 2005	Teaching hospital and comprehensive health care centre. All patients requiring blood transfusion included.	Intervention: EBMS. Bar codes used to identify patients, blood samples and blood products. Process applies to sample collection, sample arrival at blood bank, blood product dispensing and transfusion. Non-commercial system, developed in-house. Comparison: Previous processes at same hospital site: manual identification of patients information listed on a wristband. Total number of patients/transfusions/samples with outcome data not reported; hospital administers approximately 34,000 blood components per year.	Rates of sample rejection	Pre intervention: 6 months (dates unclear) Post intervention: 6 months (dates unclear)	The exact reporting period for outcome data is unclear, but outcomes 'pre-intervention' were collected in 2003 and 'post intervention' immediately after hospital-wide implementation of the intervention. The reason for the gap in reporting/choice of these dates is unclear.
Chan et al. (2004)	Study design: Retrospective before and after study Setting: Single centre, regional hospital, Hong Kong Study period: 1995 to 2002	System was installed and used in all areas of the hospital with the exception of the emergency department.	Intervention: Electronic unique patient identification barcode system used during pre- transfusion blood sampling for the compatibility test and bedside blood administration. Comparison: Manual (second-checker system) identification during blood sampling and administration.	Rates of sample rejection Rates of incorrect transfusion Procedure time	Pre intervention: 3 years (May 1999 to April 2002) Post intervention: 4 years (May 1995 to April 1999)	

Study reference	Methods, setting	Characteristics of samples/ participants	Intervention(s)	Outcomes	Follow-up period	Comments
Murphy et al. (2012)	Study design: Retrospective before and after study Setting: UK, three centres (acute hospitals within the same NHS Trust) Study period: October 2002 to October 2010	Transfusions/samples across all clinical areas.	Intervention: EBMS (Bloodtrack, Haemonetics) using bar codes for identification check at collection of blood for compatibility testing, administration of blood, and collection of blood. Comparison: Manual methods used for sample tracking/identification before the implementation of EBMS.	Rates of WBIT Rates of sample rejection Rates of incorrect transfusion Blood wastage	Pre intervention: 4 years (October 2002 to October 2006) Post intervention: 4 years (October 2006 to October 2010)	Follow up times shown are the maximum described: some outcomes were measured over shorter time periods (2 to 12 months).
Ohsaka et al. (2008)	Study design: Retrospective before and after study Setting: Single centre, Japan Study period: 2001 to 2006	All patients in inpatient wards expect the psychiatric ward, an outpatient clinic of haematology department, and operating rooms.	Intervention: Electronic transfusion management incorporating a bar code patient blood unit ID system and an automated, barcode-based process for pre-transfusion testing. Comparison: Pre-intervention period; methods used not clearly described	Blood wastage	Pre intervention: follow-up not clearly reported Post intervention: 4 years and 6 months (July 2002 to December 2006)	

Study reference	Methods, setting	Characteristics of samples/ participants	Intervention(s)	Outcomes	Follow-up period	Comments
Uriz et al. (2011)	Study design: Retrospective before and after study Setting: Spain, single centre Study period: 2006 to 2008	All transfusions within a single hospital. Average of 11,000 blood components transfused annually, but numbers included in the study are not clearly reported.	Intervention: Gricode electronic identification system (Grifols SA, Barcelona, Spain) used to track and identify blood samples and verify patient identity at each stage of blood sampling and administration. Comparison: Manual systems for transfusion procedures. A request sheet and the patients' blood sample (both identified with an adhesive label) were sent to the transfusion service, where pre-transfusion tests were performed and manually recorded in the haemotherapy control data base.	Rates of incorrect transfusion	Pre intervention: follow-up not clearly reported Post intervention: 2 years (2006 to 2008)	
Nuttall et al. (2013)	Study design: Retrospective before and after study Setting: United States, single centre Study period: 2002 to 2010	All transfusions within a single hospital.	Intervention: Electronic (barcode-based) identification of patient and blood sample before transfusion (SafeTrace Tx, Wyndgate Technologies). Comparison: Manual identification of patient/blood (systems used not described)	Rates of incorrect transfusion Near-miss events	Pre intervention: 4 years (1 January 2002 to 31 December 2005) Post intervention: 4 years (1 January 2007 to 31 December 2010) Data from 2006 was excluded due to phase-in of the intervention during this time.	The intervention is not clearly described in some aspects; it is unclear whether other steps in the sampling and transfusion process used electronic identification or remained manual.

Additional studies published after NICE Guideline NG24						
Murphy et al. (2019)	Study design: Retrospective comparative study Setting: UK, 93 centres Study period: 2015 to 2016	All UK organisations reporting to the Serious Hazards of Transfusion (SHOT) scheme were invited to participate. Ninety-three of 222 (42%) of the hospitals reporting to SHOT responded to the survey.	Intervention: Any use of electronic identification systems during blood management. This could be at any or all of the following steps in the process: 1) blood draw and sample labelling; 2) at the point of collection and delivery of blood; and 3) at the bedside for the administration of blood. Comparisons: Any use of manual procedures for patient/sample identification.	Rates of incorrect transfusion Rates of near-miss events	2 years for intervention and comparison (2015 to 2016)	Data was collected via surveys, introducing the possibility of bias due to incomplete or incorrect reporting.
Kaufman et al. (2019)	Study design: Retrospective comparative audit Setting: Unites States, Canada, New Zealand, Germany, Italy, UK. 20 centres. Study period: 1 January 2012 to 31 December 2017	Transfusion services at community hospitals and academic medical centres that regularly track total pretransfusion samples received and WBIT errors identified were eligible to participate. No information reported on the proportion of centres invited that agreed to participate.	Intervention: Electronic patient identification during sample collection and labelling (4 centres, 572,901 samples) Comparisons: Manual patient identification during sample collection and labelling (16 centres, 1,668,309 samples)	Rates of WBIT	Intervention: 12 to 32 months Comparison: 44 to 60 months Data was collected from 2012 to 2017.	Follow-up/data collection period varied between study sites; the reasons for this or the discrepancy in follow-up between interventions was not reported.
Chou et al. (2019)	Study design: Retrospective before and after study Setting: Single centre, Taiwan	All transfusions at the site during the study period were included in the analysis.	Intervention: Electronic systems used end-to-end during blood collection and transfusion. Barcodes used to label and identify patients and blood samples. Comparisons: Manual systems used for sample labelling, identification and patient/sample verification.	Rates of incorrect labelling and/or WBIT	Pre intervention: 3 years (January 2008 to December 2010) Post intervention: up to 6 years. Electronic system first	The gradual implementation period (and changes made to the intervention during this period) may mean data from this period is not representative of later outcomes. Data was

	Study period: 2011 to 2017				implemented as a pilot in 2011 and fully implemented across the hospital by 2016.	collected up to 2017, the year after the intervention was fully implemented.
Forest et al. (2017)	Study design: Retrospective before and after study Setting: United States, single centre Study period: January 2010 to December 2013	All samples received in a community hospital blood bank for blood type and screen testing during the study period were included.	Intervention: Electronic system used for blood test order entry for blood type and screen testing (SafeTrace Tx Transfusion Management Software Solution (Haemonetics Corporation, Braintree, MA) and for sample labelling. Comparisons: Previous use of manual systems for order and sample tracking.	Rates of WBIT Rates of sample rejection	Pre intervention: 1 year 5 months (January 2010 to May 2011) Post intervention: 2 years 7 months (May 2011 to December 2013)	Outcomes were measured for the year prior to and the year after implementation of the intervention.
EBMS: electronic blood management system; WBIT: wrong blood in tube.						

4.2.1 Incorrect transfusions

For this outcome we collected data that met the SHOT definition of 'wrong component transfused': "Where a patient was transfused with a blood component: of an incorrect ABO/D blood group, or which was incompatible with the recipient, or which was intended for another recipient but was fortuitously compatible with the recipient, or which was other than that prescribed e.g. platelets instead of red cells." (SHOT 2022). Five studies reported on this outcome (Chan et al. 2004, Murphy et al. 2012, Murphy et al. 2019, Nuttall et al. 2013, Uriz et al. 2011), although one of these (Uriz et al. 2011) only reported incidents of ABO-incompatible transfusion and not other incorrect transfusions. The definition of incorrect transfusions used by each study is detailed in Table 2:

One study reported no events of incorrect transfusion with either EBMS or manual systems (Chan et al. 2004). All of the remaining four studies reported numerically lower rates of incorrect transfusion events with EBMS compared to manual systems, but two of the studies (Murphy et al. 2012, Uriz et al. 2011) did not test the difference between groups for statistical significance; the other two studies reported no statistically significant difference between groups (Nuttall et al. 2013, Murphy et al. 2019).

4.2.2 Near-miss incidents

SHOT defines a 'near-miss' incident during blood transfusion as an error or deviation from standard procedures or policies that is discovered before the start of the transfusion and that could have led to a wrong transfusion or a reaction in a recipient if transfusion had taken place (SHOT 2022).

Two studies reported on this outcome. One comparative study across different centres (Murphy et al. 2019) reported near-miss events according to the step in the process where the error occurred. The rate of near-miss incidents during blood draw/sample labelling or blood collection from a refrigerator with EBMS was statistically significantly lower compared to rates with manual processes, but rates of near-miss incidents during blood administration were higher with EBMS than manual processes (Table 2). One single centre before and after study (Nuttall et al. 2013) also reported a higher rate of near-miss incidents (at any stage in the process) after implementation of EBMS than with previous manual processes (Table 2).

4.2.3 Wrong blood in tube incidents

SHOT defines WBIT errors as incidents where:

- Blood is taken from the wrong patient and is labelled with the intended patient's details
- Blood is taken from the intended patient, but labelled with another patient's details (SHOT 2021)

WBIT incidents may be detected before transfusion (resulting in near-miss incidents) or, where they go undetected, be one cause of an incorrect transfusion.

Four studies included rates of WBIT incidents (Murphy et al. 2012, Askeland et al. 2008, Forest et al. 2017, Kaufman et al. 2019). One study reported statistically significantly lower rates of WBIT incidents with EBMS; two studies reported numerically lower rates of WBIT with EBMS but did not test for statistical significance. The fourth study (Askeland et al. 2008) reported that there were zero WBIT incidents reported with EBMS, but did not report equivalent outcomes with manual processes for comparison.

A fifth study (Chou et al. 2019) reported error rates from incorrect labelling, including WBIT, but did not report WBIT separately. Authors reported statistically significantly lower error rates for EBMS compared to manual processes.

4.2.4 Sample rejection

Four studies reported this outcome (Forest et al. 2017, Askeland et al. 2008, Chan et al. 2004, Murphy et al. 2012). All of the studies reported lower rates of sample rejection for EBMS over manual processes, but only one tested for and found a statistically significant differences between the two systems: the other studies did not test for statistical significance.

4.2.5 Blood wastage

Two studies reported this outcome, one for blood wastage due to any cause (Murphy et al. 2012) and the second for wastage due to blood component expiry (Ohsaka et al. 2008). Both studies reported lower rates of blood wastage after the introduction of EBMS compared to retrospective comparison to manual processes, but only Ohsaka et al. (2008) reported a statistically significant difference between the interventions; Murphy et al. (2012) did not test for statistical significance.

4.2.6 Procedure time

One study reported the length of time taken to carry out blood sampling procedures (Chan et al. 2004). This was based on survey data and the response rate to the survey was not reported. The procedure was reported to take on average six minutes, regardless of whether EBMS or manual processes were used.

4.2.7 Other outcomes

We also searched for evidence on patient mortality due to transfusion errors, length of hospital stay and quality of life, but not identify any evidence reporting the effect of EBMS on these outcomes.

Table 2. Electronic blood management systems compared to manual systems: outcomes from primary studies

Outcome	Evidence source(s)	Type of evidence source, number of participants or transfusions	Effect of intervention	Comments on reliability
Rates of WBIT	Askeland et al. (2008)	1 before and after study. Number of participants/transfusions not reported.	Pre intervention: NR Post intervention: 0	No test for statistical significance reported. No results reported for comparison group.
	Murphy et al. (2012)	1 before and after study, 39.012 samples.	Pre intervention:1/12,322 (0.0081%) Post intervention: 1/26,690 (0.0037%)	No test for statistical significance reported.
	Forest et al. (2017)	1 before after study, 20,021 samples	Pre intervention: 1/9,907 (0.010%) Post intervention: 1/10,114 (0.0098%)	No test for statistical significance reported.
	Kaufman et al. (2019)	1 comparative study, data available for 572,901 electronic samples and 1,668,309 manual samples	Adjusted WBIT rate: Intervention: 1/14,606 (0.0068%) Control: 1/3,046 (0.033%) P < 0.0001, favours intervention	Adjusted WBIT rate accounts for repeat sample numbers and silent WBIT errors.
Rates of WBIT and/or incorrect labelling	Chou et al. (2019)	1 before and after study, 563,852 requested transfusions	Annual error rates from incorrect labelling and/or WBIT: Before intervention: 0.02 to 0.04% During rollout of the intervention: 0.01 to 0.02% After full implementation of the intervention: 0.001 to 0.002% (p <0.001 compared to before period)	
Rates of near-miss events	Murphy et al. (2019)	1 comparative study, data available for 1,946,386 blood components	Errors during blood draw and sample labelling: EBMS: 1/22,137 (0.004%) Manual processes: 1/3,474 (0.079%) Odds ratio of near-miss, EBMS vs control: 0.16, 95% CI 0.10 to 0.25 Errors during collection of blood from refrigerator: EBMS: 0/732,012 (0%) Manual processes: 1/41,379 (0.002%) Odds ratio of near-miss, EBMS vs control: 0.03, 95% CI 0.00 to 0.4	

Outcome	Evidence source(s)	Type of evidence source, number of participants or transfusions	Effect of intervention	Comments on reliability
			Errors during blood administration: EBMS: 1/20,533 (0.005%) Manual processes: 1/767,854 (0.0001%) Odds ratio of near-miss, EBMS vs control: 37.39, 95% CI 8.74 to 159.99	
	Nuttall et al. (2013)	1 before and after study; 388,837 units included pre-intervention; 304,136 units post-intervention.	Pre intervention: 1 in 388,837 units or 0.3 (95% CI <0.1 to 1.4) per 100, 000 transfusions Post intervention: 34 in 304,136 units or 11.2 (95% CI 7.7 to 15.6) per 100, 000 transfusions	Authors did not report the definition of a near-miss event used.
Rates of sample rejection	Askeland et al. (2008)	1 before and after study. Number of participants/transfusions not reported.	Pre intervention: 1.82% Post intervention: 0.17%	No test for statistical significance reported.
	Chan et al. (2004)	1 before and after study. 27,000 units of blood administered with the intervention; totals not reported for the comparison.	Pre intervention: 13 After: 0	No test for statistical significance reported.
	Murphy et al. (2012)	1 before and after study, 75,779 samples	Pre intervention:1,004/31,406 (3.2%) Post intervention: 541/44,373 (1.2%)	No test for statistical significance reported.
	Forest et al. (2017)	1 before and after study, 40,104 samples	Number of rejections in the year: Pre intervention: 243/9,907 (2.5%) Post intervention: 120/10,114 (1.2%) P < 0.001, favours intervention	Results were also reported for a second year of follow-up, for which no statistical analysis was presented. Sample rejections rate in this year were 1.3%.
Rates of incorrect transfusion	Chan et al. (2004)	1 before and after study. 27,000 units of blood administered with the intervention; totals not reported for the comparison.	Pre intervention: 0 Post intervention:0	Definition of outcome: "Blood transfused to wrong patients"

Outcome	Evidence source(s)	Type of evidence source, number of participants or transfusions	Effect of intervention	Comments on reliability
	Uriz et al. (2011)	1 before and after study. Number of participants/transfusions not clearly reported.	Pre intervention: median 2 wrong ABO-type transfusion events per year Post intervention = 0 (from 2005 to 2008)	Definition of outcome: "wrong ABO-type transfusion events" No test for statistical significance reported. The length of follow-up for the pre-intervention period was not clearly reported.
	Nuttall et al. (2013)	1 before and after study; 388,837 units included pre-intervention; 304,136 units post-intervention.	Pre intervention: 1 in 64,806 units or 1.5 (95% CI 0.6 to 3.3) per 100, 000 transfusions Post intervention: 1 in 304,136 units or 0.3 (95% CI <0.1 to 1.8) per 100, 000 transfusions	Definition of outcome: "a blood product transfused to the wrong patient"
	Murphy et al. (2012)	1 before and after study, 95,458 transfusions	Pre intervention:1/27,523 (0.0036%) Post intervention: 1/67,935 (0.0014%)	Definition of outcome: "wrong blood-transfused events" No test for statistical significance reported.
	Murphy et al. (2019)	1 comparative study, data available for 1,946,386 blood components	EBMS: 1/379,753 (0.00026%) Manual processes: 1/254,126 (0.00039%) Odds ratio of incorrect transfusion, EBMS vs control: 0.41, 95% CI 0.12 to 1.47 (favours neither intervention)	Definition of outcome: SHOT definition (see Section 4.2.1) Measured using survey data, and therefore at risk of recall and response bias
Procedure time, minutes	Chan et al. (2004)	1 before and after study. 27,000 units of blood administered with the intervention; totals not reported for the comparison.	EBMS: 6 Manual process: 6	Measured using survey data, and therefore at risk of recall and response bias. Unclear what proportion of total transfusions are accounted for by survey data.

Outcome	Evidence source(s)	Type of evidence source, number of participants or transfusions	Effect of intervention	Comments on reliability
Rates of blood wastage	Murphy et al. (2012)	1 before and after study, 53,220 units	Pre intervention: 490/27,418 (1.8%) Post intervention: 336/25,802 samples (1.3%)	No test for statistical significance reported.
Rate of date-expired blood components, mean (SD)	Ohsaka et al. (2008)	1 before and after study, 49,974 blood components	Pre intervention: 0.65 (0.55) Post intervention: 0.30 (0.17) P <0.0001	No test for statistical significance reported. Total number of blood components included in study is reported but it is unclear what proportion were before/after intervention.

EBMS: electronic blood management systems; NR: not reported; SD: standard deviation; WBIT: wrong blood in tube

4.3 Certainty of the evidence

This section highlights any gaps, uncertainties, or issues with the reliability and/or generalisability of the evidence.

- The majority of evidence identified comes from before-and-after studies (8/10 total studies identified) measuring outcomes with EBMS after its implementation in a single centre compared to outcomes before its introduction. All these studies either collected data retrospectively or did not state when data collection began relative to the study. Such use of 'historic controls' can introduce bias, due to the difficulty of controlling for confounding factors that could have influenced outcomes in addition to the intervention itself. Some study authors acknowledged this limitation, but none appear to have explored methods to control for possible confounding. Understandably, the introduction of a complex intervention such as EBMS across a hospital requires a phased implementation period; three studies clearly described methods to account for this (usually by excluding outcome data over the 'phase in' period, although if this was applied retrospectively there remains potential for bias), and a further three measured 'before' and 'after' outcomes over several years, but the remaining two did not make clear how any implementation period was accounted for in measuring outcomes. Three studies also did not report full details of the period over which outcomes were measured before and after the introduction of EBMS.
- The remaining two studies compare outcomes across centres that used different types of blood management systems (either electronic or manual). This allows for comparison of outcomes across different centres, using different systems, over a static time period and avoids some of the risks of bias discussed above. However, there is still potential confounding from other causes, and since these studies recruited centres based on survey responses/willingness to participate in the study, there is potential for bias based on receipt of selective sample of responses and (intentional or otherwise) selective reporting of data by the centres that responded.

4.4 Ongoing trials

Our searches did not identify any ongoing trials relevant to the research question.

5. Health Economics

5.1 Health economic evidence review

The titles and abstracts of 6,078 records identified in the search for this research question were screened and no health economic studies were deemed potentially relevant. As such, no health economic studies have been included in this evidence appraisal report.

The NICE Blood transfusion guideline (NG24) included a review question on the clinical and cost effectiveness of electronic patient identification systems (NICE 2015). No health economic evaluations were included in NG24, however the guideline committee was informed in its discussions by a non-comparative study by (Murphy et al. 2012), which describes the implementation of an electronic blood transfusion management system (BloodTrack) in Oxford University Hospitals NHS Trust in 2006/2007. This study was excluded from the NG24 review as the study was non-comparative; it did not compare the cost of BloodTrack with the cost of transfusion management prior to the implementations of the electronic system.

(Murphy et al. 2012) reported that preliminary estimates of the costs are £390,308 (reported as $575,000, cost year 2011) per year for a managed service contract, which comprises leasing of the hardware (handheld computers and mobile printers), electronically controlled blood refrigerators, software licenses and training.

The study further reported estimates of efficiency gains as a result of the implementation of the electronic blood transfusion management system, to which it attributes cost savings which offset the cost of the system. However, it is unclear whether any statistical analysis was conducted to control for confounding, and the sources of unit costs and detail of calculations are not available in the study. The study reported savings in nurse time (1 fewer nurse and a 50% reduction in nurse time for pre-transfusion bedside checking (saving £566,614 per year), reduced laboratory staff time due to fewer rejected samples (saving £22,400 per year), reduced cost due to RBC unit wastage (saving £22,400 a year) and reduced blood costs as a result of reduced usage of RBC units (only partially attributable to the electronic system) (saving £444,612 a year). Despite the limitations of the study, these findings were considered by the NG24 guideline committee to be reasonable, and the committee concluded that the electronic patient management system was likely to be cost effective (NICE 2015). The committee noted that costs would vary depending on the existing IT infrastructure and chosen system within trusts and the individual hospital's transfusion rates and processes. The committee highlighted further likely efficiency gains in meeting traceability obligations to regulators (NICE 2015).

5.2 HTW health economic analysis

EBMS are a digital health technology and are considered to be a low financial commitment according to the NICE Economic Impact Standards Framework for Digital Health Technologies. National commissioning decisions for digital health technologies which are expected to be cost-saving are considered to be a medium risk to the payer (as implementation costs may be significant but it is expected to be cost-saving overall) and the financial commitment is therefore considered to be low.

The NICE economic impact standards are designed to highlight what information is needed for an effective economic analysis, recognising that the type of economic analysis undertaken should be determined by the financial consequences of adopting and implementing the digital health technology from a payer or commissioner perspective. The appropriate level of economic analysis depends on the type of decision needed and likely financial commitment. For low financial commitment technologies, it is recommended that a cost-consequence analysis is produced to demonstrate effectiveness of the technology. This allows exploration of whether differences in expected costs between options can be justified in terms of expected benefits. It is expected that there will be sensitivity analysis to explore the uncertainties in the model. The results can be used to inform a budget impact analysis.

5.2.1 Approach

The Scottish Health Technologies Group (SHTG) produced a cost analysis of a Unique Device Identifier system compared with existing health board-level processes for recording, identifying and recalling medical devices (SHTG 2021). The cost analysis quantified staff resource use to which the unit costs staff time were applied.

HTW followed a similar approach in developing a cost analysis to compare the costs of the following interventions in NHS Wales over a two-year time horizon:

- Vein-to-vein EBMS
- Paper-based system.

A paper-based system was used as the comparator for this analysis as a conservative assumption, whereas experts advise that some hospitals in Wales already use the courier EBMS module. Nowhere in Wales has full vein-to-vein technology.

The results of the cost analysis should be considered alongside the potential benefits of the system outlined in the 'clinical effectiveness' section of the evidence appraisal report.

5.2.2 Electronic blood management system costs

(Murphy et al. 2012) reported preliminary estimates of the cost of BloodTrack at £390,308 (reported as $575,000, cost year 2011) per year for a managed service contract, which comprises leasing of the hardware (handheld computers and mobile printers), electronically controlled blood refrigerators, software licenses and training. The setting for the study was three acute hospitals comprising the Oxford University Hospitals (OUH) NHS Trust. After implementation, the study notes that the coverage of BloodTrack was 111 clinical areas. OUH is served by one large laboratory providing a centralised service for the Oxford hospitals, a satellite laboratory and a small pathology laboratory.

A NICE Quality and Productivity Case Study on the implementation of BloodTrack at OUH notes that a project management team was appointed, including a full-time project manager working for OUH and a project manager working for the original commercial supplier (Oxford University Hospitals 2013). In addition, OUH employs a senior manager to ensure the correct day-to-day running of the system. We included the costs of a project manager and a senior manager per health board to cover the planning/implementation phase in year 1, and the ongoing costs of a system manager per health board.

It is uncertain whether Bloodtrack training costs, which were included in the (Murphy et al. 2012) cost, include staff time for training. We have therefore included estimated staff time costs for training separately, as a conservative assumption. We included estimates of the cost of initial training of staff in year 1, and ongoing costs for training (to allow for staff turnover).

Assuming that the EBMS would be implemented in 13 major A&E hospitals, 25 minor injury units and 2 acute hospitals in Wales, and assuming that the system would cover 16 clinical areas in each, the cost in year 1 was £5,681,996 and £3,879,549 in subsequent years (cost year 2021). The average number of clinical areas covered was varied in sensitivity analyses.

The BloodTrack cost from (Murphy et al. 2012) was favoured in the base case, as experts advise that it is a full vein-to-vein system, which is interoperable with the laboratory IT system in Wales. The cost of an alternative EBMS was used in a sensitivity analysis. The acquisition cost of Msoft Blood360 is quoted on the UK Government Digital Marketplace as between £0.50 and £5 per device per day (UK Government Digital Marketplace 2020). The six-month 'Getting Started Pack' offered by the company comprises the Blood360 hub, 5 'Enterprise' app licences, two 'Porter' app licenses, five 32Gb apple iPods, one 'collect and go' fridge and one lab interface, the up-front setup charge is £3,999 +VAT and an additional £6,000 per six month period of cloud charges. This is suggested to cover 16 clinical areas. Based on the suggested resource use in the 'Getting Started Pack, the estimated cost beyond the trial period would be £19,246 per hospital per six month period, or £38,492 per hospital annually (table 3). The lifetime of the hardware is not considered in the calculations as hardware is not owned by the hospital, but on loan from Msoft.

The annual acquisition cost per clinical area for Blood360 is £2,406 compared with £3,516 for BloodTrack as reported by (Murphy et al. 2012). The difference in cost could be explained by

possible differences in cost items included; Msoft Blood360 cost does not include items such as planning costs prior to adopting the system and training, for example. It is not clear whether Blood360 is a full vein-to-vein system.

Table 3. Electronic blood management system costs

Item	Unit cost	Resource use	Total cost	Source
Base-case: Bloodtrack - Year 1 only				
Planning phase: Project manager (band 7)	£42,376	1 FTE per health board , 7 health boards	£296,632	Resource use based on assumption. Unit cost of health and social care staff 2019/2020, PSSRU (Curtis & Burns 2020)
Planning phase: Senior manager (average bands 8a-8c)	£57,532.33	1 FTE per health board, 7 health boards)	£402,726	Resource use based on assumption. Unit cost of health and social care staff 2019/2020, PSSRU (Curtis & Burns 2020)
Training	Laboratory staff: £49 per hour Nursing staff: £41 per hour	1 hour; 100% of staff (Scenario: 50% of staff)	£1,742,635	Staff band and time for training based on assumption. Cost for delivering training assumed included in Bloodtrack cost. Staff numbers: Estimate of relevant nursing staff 33,817 (StatsWales 2021a) And laboratory staff: 7,228 (StatsWales 2021b)
Base-case: Bloodtrack - Ongoing				
System manager (average bands 8a-8c)	£57,532.33	1 FTE per health board, 7 health boards	£402,726	Resource use based on assumption.
Training (year 2+)	Laboratory staff: £49 per hour Nursing staff: £41 per hour	1 hour; assuming 36.7% turnover (Scenario: 27% turnover)	£639,547	Resource use based on % of nurses in Wales who reported expecting, considering or strongly considering leaving by end of 2020. Scenario: 2019. Assumption applied for laboratory staff also. (RCN Wales 2021)
Bloodtrack	£4,433 [a] per clinical area	16 clinical areas per hospital. 40 hospitals	£2,837,276	(Murphy et al. 2012)
		Total cost (Wales)	Year 1: £5,681,996 Ongoing: £3,879,549	
Scenario analysis: Blood360 - Year 1 only				
Planning and training	As for Bloodtrack			
Up-front set up cost	£3,999	1	£3,999	The Trial covers 16+ 'areas' – giving the Trust the freedom to use the devices in any area. Source (UK Government Digital Marketplace 2020)

Item	Unit cost	Resource use	Total cost	Source
Six month trial period cloud charges	£6,000 per month	1	£6,000	The Trial covers 16+ 'areas' – giving the Trust the freedom to use the devices in any area. Source (UK Government Digital Marketplace 2020)
Scenario analysis: Blood360 - Ongoing				
System manager and training	As for Bloodtrack			
Blood360 hub (provides all web application services to web browsers and devices. Implementation, hosting services and setup included)	£500 per month	1	£500 per month	(UK Government Digital Marketplace 2020) Resource use based on suggested in 'Getting Started' pack for Blood 360, suggested to cover 16 clinical areas
Enterprise app license >50 devices	£22.52 per month per device	5	£112.60 per month	
Porter app license >50 devices	£30 per month per device	2	£150.10 per month	
32Gb apple iPod (Apple 2021) Supported portable handheld device	£199	5	£995 per month	
'Collect and go' fridge	£150 per month	1	£150 per month	
Lab interface: Compatibility Label Printer with 2D Barcode Check	£200 per month	1	£200 per month	Resource use based on assumption
Lab interface: Batch Products Printer (Lab)	£200 per month	1	£200 per month	Resource use based on assumption
UAT/ Training Cloud Space	£150 per month	1	£150 per month	Resource use based on assumption
Offsite Professional Services (maintenance)	£750.00 + vat per day	1	£750 per month	Resource use based on assumption
Total cost (Wales)			Year 1: £4,014,524 Ongoing: £2,581,961	

[a] 2021 GBP, inflated from 2011 GBP using health consumer price indices (ONS 2021)

The population affected by the implementation of an electronic blood management system would include all people requiring a group and screen sample, or who require transfusion of a blood component. As a conservative assumption, we have not included an estimate of the number of people who require a group and screen sample in the base case, as a proportion of these are likely to receive a transfusion. In 2020, the Welsh Blood Service issued 93,405 blood components (SHOT 2021). Assuming that 1.6% of blood components were wasted, based on the overall blood product wastage in (Murphy et al. 2012), and assuming that one blood product was transfused per person, gives an estimated population size of 91,911. In the base case, the cost of Bloodtrack per person transfused would be £61.82 in year 1 and £42.21 thereafter (table 4). Alternative population size estimates were used in sensitivity analyses.

Table 4. EBMS cost per person, using alternative population size estimates

Population size	EBMS cost per person		Notes
	Year 1	Year 2+	
91,911	£62	£42	Based on Welsh blood service total blood components issued (base case)
45,955	£124	£84	Based on Welsh blood service total blood components issued (two components transfused per person)
3,704	£1,534	£1,047	Patient Episode Database Wales. HRG SA44 (Single Plasma Exchange or Other Intravenous Blood Transfusion)
8,769	£648	£442	NHS Reference Costs 18/19 HRG SA44. ONS Mid 2020 population estimates used for Wales weighting
2,775,560	£2	£1	NHS Reference Costs 18/19 number of tests (integrated blood services). ONS Mid 2020 population estimates used for Wales weighting
499,593	£11	£8	NHS Reference Costs 18/19 'Cross match blood/group and save serum for later cross match' HRGs VB01, VB04, VB05, VB07, VB08. ONS Mid 2020 population estimates used for Wales weighting

EBMS: Electronic blood management systems; HRG: Healthcare Resource Group; ONS: Office of National Statistics

5.2.3 Staff time

In addition to the cost for acquisition of an electronic blood management system, we accounted for the costs of staff time for using EBMS and paper-based systems. A white paper obtained from the website of the manufacturer of BloodTrack (Haemonetics) reports clinical and laboratory staff time before and after implementing BloodTrack at the John Radcliffe Infirmary in Oxford. The white paper does not state whether the reported savings in staff time are per patient, nor does it specify the population. It is therefore unclear whether the reported savings represent staff time for delivering a transfusion, emergency blood delivery, undertaking a group and screen sample, or an average across each of these situations, for example. We assume the reported resource use data represent staff time per person transfused. Staff bands were based on assumptions, and staff time was costed using the 2019/2020 Unit Costs of Health and Social Care (table 5) (Curtis & Burns 2020).

Table 5. Resource use per transfusion, for electronic and paper-based blood management systems

Resource item	Staff band	Cost per minute [b]	Time (minutes) [c]	Total cost
EBMS				
Laboratory staff time	Average band 4-7	£0.81	17	£11.66
Clinical staff time	Band 5 [a]	£0.69	17	£13.77
			TOTAL	**£25.43**
Paper-based				
Laboratory staff time	Average band 4-7	£0.81	59	£39.77
Clinical staff time	Band 5 [a]	£0.69	58	£47.80
			TOTAL	**£87.57**

[a] Band 5. Nurses enter the NHS workforce at band 5. 46% of nurses are at band 5 in Wales (RCN Wales 2021).
[b]Source: Unit cost of health and social care staff 2019/2020, PSSRU (Curtis & Burns 2020)
[c]Source: (Haemonetics 2019) Resource use from John Radcliffe Infirmary, Oxford

5.2.4 Results

The base case results of the cost analysis demonstrate that EBMS saves £0.32 per person in the first year and £19.93 per person in each subsequent year (table 6). Table 7 shows the results of several deterministic sensitivity analyses.

A threshold analysis was conducted on the cost of staff time using EBMS. To be cost saving over 5 years, the cost of staff time per transfusion would need to be £41, compared with £88 with a paper-based system.

Table 6. Base case cost analysis results

	EBMS	Paper-based	Difference
System cost per person year 1	£61.82	£0	
System cost per person year 2+	£42.21	£0	
Staff time per transfusion	£25.42	£87.57	
Total			
Total cost year 1	£87.25	£87.57	EBMS saves £0.32
Total cost year 2+	£67.64	£87.57	EBMS saves £19.93

EBMS: Electronic blood management systems

Table 7. Results of deterministic scenario analyses

Scenario	Result
Base case	Year 1: Saves £0.32 Year 2: Saves £19.93
Number of clinical areas per hospital changed to 20 from 16	Year 1: £7.40 Year 2: Saves £12.21
50% of staff trained initially	Year 1: Saves £9.80 Year 2: Saves £19.93
Staff turnover 27%	Year 1: Saves £0.32 Year 2: Saves £21.77
MSoft Blood360	Year 1: Saves £18.46 Year 2: Saves £34.05
Population estimate based on Welsh Blood Service numbers of products issued, with assumption that two products are issued per person on average	Year 1: £61.50 Year 2: £22.28
Population estimate based on Patient Episode Database Wales, HRG SA44 (Single Plasma Exchange or Other Intravenous Blood Transfusion)	Year 1: £1472 Year 2: £985
Population estimate based on NHS Reference Costs 18/19 HRG SA44. ONS Mid 2020 population estimates used for Wales weighting	Year 1: £586 Year 2: £380
Population estimate based on NHS Reference Costs 18/19 number of tests (integrated blood services). ONS Mid 2020 population estimates used for Wales weighting	Year 1: Saves £60.09 Year 2: Saves £60.74
Population estimate based on NHS Reference Costs 18/19 'Cross match blood/group and save serum for later cross match' HRGs VB01, VB04, VB05, VB07, VB08. ONS Mid 2020 population estimates used for Wales weighting	Year 1: Saves £50.77 Year 2: Saves £54.38
EBMS nursing and laboratory staff time increased by 100% (minutes total)	Year 1: £25.11 Year 2: £5.50
No difference in staff time between EBMS and paper-based	Year 1: £61.82 Year 2: £42.21
EBMS: Electronic blood management systems; HRG: Healthcare Resource Group; ONS: Office of National Statistics	

5.2.5 Discussion

- For simplicity, this cost analysis focused only on savings due to staff time when using the system. No consideration has been made of other outcomes, such as wrong blood in tube events. A reduction in wrong blood in tube events could prevent the need for repeat samples to be taken from patients. This would result in further cost savings.
- It is uncertain whether the Bloodtrack cost includes the costs of changes to infrastructure (Wi-Fi networks and network points). These costs have not otherwise been accounted for in this cost analysis, which could bias the results in favour of EBMS.
- We have not included the costs of consumables. As experts report that fewer samples are required with EBMS due to the eliminated requirement for two independent samples to be taken, this could bias the results in favour of paper-based systems.
- The source for the estimates of staff time was a white paper from the Haemonetics website (BloodTrack manufacturer).
- There is uncertainty in the population size, which affects the results.

6. Organisational Issues

We identified one systematic review (Sellen et al. 2015) and one primary study (Murphy et al. 2009) discussing issues around the implementation of EBMS. We also gathered comments on this issues from expert reviewers. The following issues were highlighted:

- Introducing EBMS can be a complex change that needs the support of all those involved, such as hospital management and clinical/laboratory staff. Previous examples of implementation in the UK involved dedicated project management staff (Murphy et al. 2009). This and other examples in the existing evidence describe using a stage approach when introducing the system (Murphy et al. 2009, Sellen et al. 2015).
- As well as clear communication and explanation of the benefits to them/why change is warranted, the latter group will also require training in the new systems. Continuous, rather than one-off, training in use of the systems involved is likely to be required. Examples of successful implementation noted the availability of technical staff familiar with the system to assist clinical and laboratory staff with troubleshooting during the early phases of implementation (Murphy et al. 2009).
- Depending on the scope of implementation, multiple existing IT systems may need to be interfaced with the new system. Although the infrastructure involved should be robust and we found no evidence of consequences of IT system failures, experts consulted and SHOT recommendations both note that a back-up manual system will also need to be maintained in case of IT failure.

During the production of our report, work has commenced on a Discovery and Scoping project to explore in greater detail how Wales-wide EBMS could be implemented.

7. Patient issues

Expert reviewers highlighted the important safety concerns around the potential for patient to receive the wrong blood sample. Expert reviewers also highlighted potential benefits to patients from the use of EBMS if rates of sample rejection are lower. Sample rejection means blood needs to be drawn a second time, meaning the patient must undergo the procedure, and experience the associated pain and discomfort, for a second time. For outpatients, sample rejection might also mean an extra trip to return and give a second sample.

8. Contributors

This topic was proposed by Indu Thakur, Consultant Paediatric Haematologist, Cardiff and Vale University Health Board .

The HTW staff involved in writing this report were:

- D Jarrom: clinical effectiveness review, co-author of EAR
- S Hughes: health economics review, co-author of EAR
- E Hasler: literature searches & information management
- L Elston: clinical effectiveness quality assurance
- M Prettyjohns: health economics quality assurance
- A Evans: patient and public involvement

The HTW Assessment Group advised on methodology throughout the scoping and development of the report.

A range of clinical experts from the UK provided material and commented on a draft of this report. Their views were documented and have been actioned accordingly. All contributions from reviewers were considered by HTW's Assessment Group. However, reviewers had no role in authorship or editorial control, and the views expressed are those of Health Technology Wales.

Experts who contributed to this appraisal:

- Samantha Mcwilliam, Transfusion Practitioner, Bloodbank, Cardiff and Vale University Health Board
- Mike Murphy, Professor of Transfusion Medicine, University of Oxford; Consultant Haematologist, NHS Blood & Transplant and Oxford University Hospitals NHS Foundation Trust
- Andy Goringe, Consultant Haematologist – Clinical lead for transfusion – Cardiff and Vale University Health Board
- Lee Wong, National Blood Health Team Lead, Welsh Blood Service
- David Mason-Hawes, Head of Digital Delivery, Welsh Blood Service
- Lorraine Lewis Prosser, Transfusion Practitioner, Aneurin Bevan University Health Board
- Nicola Polley, Clinical Specialist, Haemonetics

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10. Evidence review methods

We searched for evidence that could be used to answer the review question: What is the clinical and cost-effectiveness of electronic blood management systems (EBMS) compared to standard methods of blood management?

A systematic literature search for evidence was undertaken and was last updated on the 27th of January 2022. Appendix 3 gives details of the search strategy used for MEDLINE. Search strategies for other databases are available on request. The criteria used to select evidence for the appraisal are outlined in Appendix 1. These criteria were developed following comments from the Health Technology Wales (HTW) Assessment Group and UK experts.

Initial screening of the literature identified an evidence review carried out as part of a NICE Guideline (NG24: Blood Transfusion) on the research question: "What are the clinical- and cost-effectiveness of electronic patient identification systems such as patient identification band, bar code or radiofrequency identification (RFID) to ensure patient safety during blood transfusions?" This question and associated review protocol was sufficiently similar to our proposed question and protocol to allow for adaptation. We therefore used NICE's evidence review as a source of studies up to their last date of search (29 January 2015). We elected not to screen literature published before this date, and amended our protocol to apply a date limit of end of January 2015.

We identified two further partially relevant systematic reviews published shortly prior to NICE's review (Sellen, 2015; Cottrell, 2013). To minimise the risk of omitting studies by applying a date limit, we also checked the included studies within these review for relevance, but did not identify any studies meeting our inclusion criteria that were not already included in NICE's review.

Appendix 2 summarises the selection of articles for inclusion in the review.

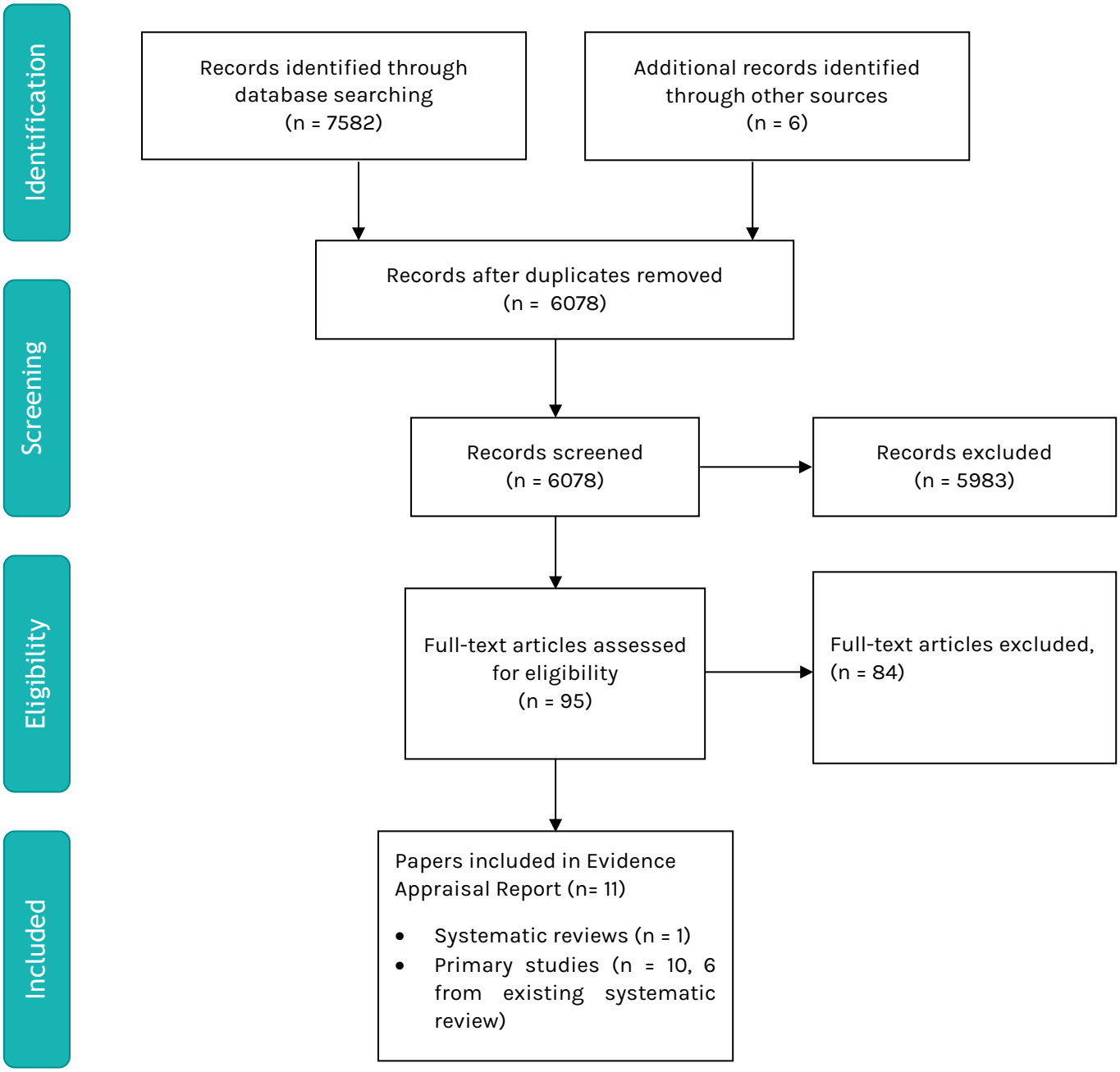
For studies included in NICE's review, we adapted reporting of study characteristics and outcome data reported by NICE. For all studies included by NICE, we obtained full texts and extracted any further data required by this review not reported by NICE. For studies identified prior to NICE's review, we also obtained full texts and extracted the data shown in tables 1 and 2. The mixture of study designs and methods of outcome reporting across studies meant meta-analysis was not considered appropriate and all data was reported narratively.

Appendix 1. Inclusion and exclusion criteria for evidence included in the review

	Inclusion criteria
Population	All people undergoing blood transfusions or associated procedures such as 'group and screen' sampling
Intervention	Electronic blood management systems including but not limited to: • BloodTrack • EGIS eTraceline • Msoft Blood360 • Scan4Safety
Comparison/ Comparators	Standard care. This could include any current method of blood management, including but not limited to: • Manual methods of blood management/patient identification • A combination of manual and electronic methods
Outcome measures	• Rates of inappropriate transfusion ('never events' and 'WBIT') • Overall rates of transfusion • Rejected samples due to errors/blood waste • Time to access/check blood • Patient safety – mortality, transfusion errors • Length of hospital stay • Quality of life • Healthcare resource use • Cost

Study design	We will prioritise the following study types, in the order listed: • Systematic reviews of randomised controlled trials. • Randomised controlled trials. • Non-randomised comparative trials. • Single-arm (no control group) trials that report any relevant outcome. We will only include evidence from "lower priority" sources where this is not reported by a "higher priority" source. This could be because higher priority evidence: • Does not cover all relevant populations • Does not compare the technology of interest to all relevant comparators • Does not cover all outcomes of interest • Reports over short-term follow up periods, and longer follow up data is required to facilitate decision making. Where relevant and well-conducted systematic reviews exist we will use these by: • Reporting or adapting their reported outcome measures where these are fully relevant to the scope of our review, and appropriate synthesis methods have been used • Using these reviews as a source of potentially relevant studies where the review cannot be used as a source of outcome data We will prioritise systematic reviews in terms of the sources of evidence they include, using the order described above.
Search limits	We will use Evidence Review C10: "Electronic Patient Identification Systems", from 'NICE Guideline NG24: Blood Transfusion' as a source of evidence up to 29 January 2015. We will carry out our own searches for evidence published from the date of last search used in Evidence Review C10.
Language limits	English language only
Publication status	We will include evidence from studies that are published in full. We will only include evidence from conference abstracts if there are critical gaps in the fully published evidence. We will include details of any ongoing trials that have a planned completion or reporting date within 24 months of the date searches are carried out. We will only include trials of a design that is likely to add to the existing evidence in terms of certainty; for example, if we report evidence from randomised controlled trials in the EAR, we will only report details of ongoing trials if they also use a randomised design.
Amendments to the protocol	As detailed in Methods, we initially applied no date limited to our searches, but added the date limit detailed above after undertaking searches and preliminary literature screening.

Appendix 2. Flow diagram outlining selection of relevant evidence sources



Appendix 3. Medline search strategy

Ovid MEDLINE(R) ALL 1946 to January 26, 2022		
Transfusion / blood management terms		
1	(bloodtrack* or blood track*).tw,kw.	23
2	*Blood/	29666
3	Blood Banks/	7387
4	Transfusion Medicine/	321
5	exp Blood Transfusion/	89877
6	*Blood Specimen Collection/	6531
7	(bloodbank* or blood bank*).tw.	6756
8	((blood or platelet) adj transfusion*).tw.	52401
9	transfusion practice*.tw.	1971
10	exp Transfusion Reaction/	16433
11	Blood Group Incompatibility/	6412
12	((blood* or transfusion*) adj3 (incompat* or observat* or adverse* or reaction*)).tw.	13481
13	(blood adj3 manag*).tw.	5975
14	or/2-13	186649
Technology / electronic records management terms		
15	Patient Identification Systems/	2142
16	patient identi*.tw.	2940
17	*Medical Records/	45431
18	*"Forms and Records Control"/	2556
19	Medical Records Systems, Computerized/	19130
20	*Electronic Health Records/	14823
21	*Electronic Data Processing/	7202
22	(electronic health record* or EHR).tw.	22346
23	(electronic patient record* or EPR).tw.	25864
24	*Information Technology/	407
25	*Automation/	4399
26	*Automation, Laboratory/	1051
27	*Software/	47711
28	*Electronics/	4595
29	*Electronics, Medical/	2583
30	((information or digital) adj technolog*).tw.	17012
31	(automation adj5 (blood* or transfus*)).tw.	154
32	(electronic adj3 (system* or control*)).tw.	18935
33	(virtual adj3 system*).tw.	2389
34	Medical Informatics/	12677
35	Medical Informatics Applications/	2549
36	Medical Informatics Computing/	761
37	informatics.tw.	13778
38	Product Labeling/	2849
39	Computers, Handheld/	3929
40	((handheld* or hand held*) adj3 scan*).tw.	303
41	Radio Frequency Identification Device/	600
42	(radiofrequency identif* or radio frequency identif* or rfid*).tw.	1450
43	(bar cod* or barcod*).tw.	11657
44	(wristband* or wrist band*).tw.	672
45	printer.tw.	3625
46	((portable or mobile) adj3 scan*).tw.	608
47	Information Systems/	19227

48	Inventories, Hospital/	1089
49	Medical Order Entry Systems/	2395
50	Hospital Distribution Systems/	621
51	Hospital Information Systems/	11034
52	Clinical Laboratory Information Systems/	2101
53	Mandatory Reporting/	3421
54	*"Blood Grouping and Crossmatching"/st [Standards]	108
55	*Medical Errors/pc [Prevention & Control]	5290
56	Medication Errors/pc [Prevention & Control]	6716
57	*Patient Safety/	11747
58	*Safety Management/	13789
59	Monitoring, Physiologic/st [Standards]	1803
60	(blood adj2 administration).ti.	348
61	vein-to-vein.tw.	1069
62	or/15-61	321201
Set combinations		
63	14 and 62	1803
64	transfus* observation*.tw.	12
65	(wrong blood in tube or WBIT).tw.	39
66	((right blood or right unit) and right patient).tw.	13
67	or/63-66	1832
68	1 or 67	1852
69	limit 68 to english language	1581
70	exp animals/ not exp humans/	4948871
71	69 not 70	1539