# QUALITY IMPROVEMENT CAN DECREASE BLOOD DELIVERY TURNAROUND TIME: EVIDENCE FROM A SINGLE TERTIARY-CARE ACADEMIC MEDICAL CENTER

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## Abstract

**Context:** Blood transfusion services are critical to any hospitals' functioning, and timely blood/ component therapy resuscitation is lifesaving. Yet, few blood delivery turnaround time (TAT) studies have been undertaken.

**Aims:** We assessed blood delivery TAT at our institution before and after implementing an intervention.

*Settings and Design:* This before-after study assessed blood delivery TAT at our institution at baseline (first audit, December 2015 - February 2016); analyzed the causes of any delays and implemented a multipronged organizational, educational and operational remedial actions for risk mitigation for 3 months, aiming to shorten the blood delivery TAT; and then 9 months later assessed the blood delivery TAT again (second audit, November 2017 - December 2017).

**Methods and Material:** For each of the two audits, we assessed three indices that comprise TAT: response time (time from doctor's request until blood is ready for collection, T1); processing time (time from the arrival of technician to blood bank and start of paperwork processing at the blood bank's front desk until actual collection of the blood, T2); and, Transport time (time from blood bank to arrival to operating theatre, T3).

**Statistical analysis used:** The observed proportions for categorical variables were reported as percentage and compared using Chi square test.

**Results:** After implementing the remedial actions, the second audit confirmed considerable improvements across all three components that comprise the blood TAT. The transport time significantly decreased from an initial majority of > 15 mins duration, to a majority of < 15 mins transport time after the second audit; there was a 50% improvement in 30 mins response time; and the percentage of requests processed in < 10 mins were significantly higher after the second audit.

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**Conclusions:** Our program and its findings in terms of much improved blood delivery TAT after implementing this quality improvement approach represent an appropriate and effective solution to the challenge of making blood available fast enough to meet true hemorrhagic emergencies.

**Keywords:** Turnaround time, intraoperative, monitoring, blood banking/ transfusion medicine, blood components.

## Introduction

Blood transfusion services are vital to health care systems and overall medical management[1]. When unpredicted surgical blood loss that poses risks for patients occur, timely arrival of blood from the blood bank is essential, and fast and efficient transfusion is of utmost importance[2,3]. In addition, the increasing life expectancy and mean age of the population, and the rising number of new therapeutic opportunities suggest that the need for blood products will stay stable over time[3]. In the USA, estimated whole blood and red blood cell collections in 2013 totalled 13.6 million units, and transfusions of white and red blood cells (RBC) units summed up to 6.1 million units[4].

The systemic effects of whole blood transfusions confirm the effectiveness of this therapy[5]. Hemorrhagic shock is a leading cause of preventable death[6]; and hypovolemic shock has many detrimental effects[1]. With early transfusion, such life-threatening conditions can have improved outcomes[7].

Several issues characterize blood transfusion administration. First, blood administration costs add to the blood products costs. In UK hospitals, the annual blood administration costs, excluding blood products, exceeded $175 million[8]. In addition, blood transfusion affects many patients, and transfusion services comprise a multi-stakeholder complicated system (hospital blood bank, patient ward, emergency department, operating room, transfusionist, transporter)[9]. Hence, the timely delivery of required blood is a key blood bank performance indicator, where delays in making blood accessible can make an enormous difference[10].

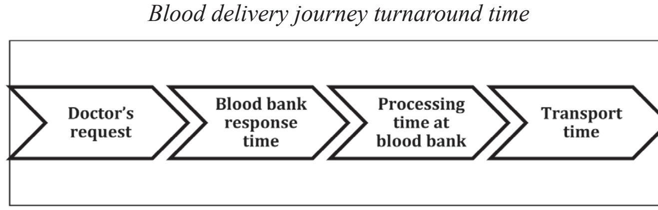
Given such necessity, demand, costs, and time sensitivity of blood and its products despite the complex delivery systems, the turnaround time (TAT) of issuing blood products is a process quality indicator, albeit not an established benchmark[11]. However, although the efficiency of clinical workflow in the healthcare sector is under constant surveillance[10], yet, few blood transfusion process TAT studies have been undertaken. In the USA, blood transfusion process research has been conducted to reduce the risk of problems intrinsic to the procedure[9]. TAT standards should be established and monitored for quality improvement of transfusion services[2]. Nevertheless, most blood banks do not monitor blood-product TAT[11]. There seems no established TAT yardstick for blood-product issuance within the transfusion medicine discipline[10,12], and many academic establishments do not monitor TAT as a quality indicator[11]. Quality markers in transfusion medicine gauge the organizational performance of laboratory services, ensure patient safety and assess customer satisfaction[11,13].

We divided blood delivery TAT into three phases[11]: Response time (time taken from doctor's request until blood is ready for collection, T1); Processing time (time taken from the arrival of technician to blood bank and start of paperwork processing at the blood bank's front desk until the actual collection of the blood, T2); and, Transport time (time taken from blood bank to arrival to operating theatre, T3).

## Aim of the Study

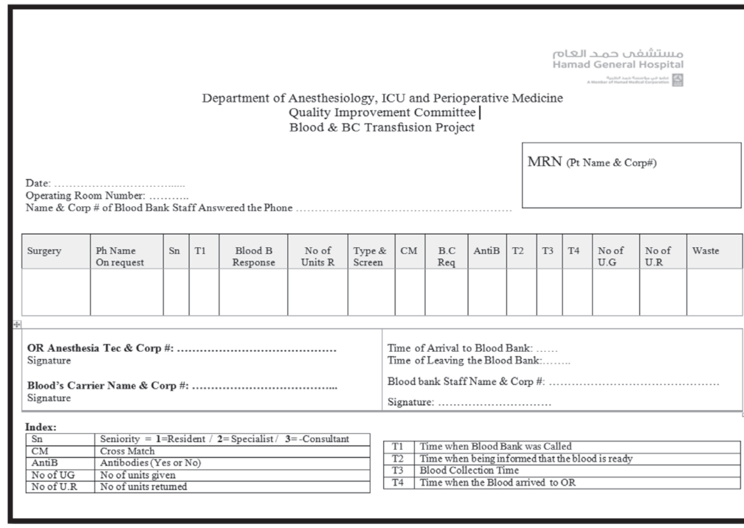
The current before-after study assessed blood delivery TAT (baseline measurement during December 2015 - February 2016) at our institution. We assessed the 'request-to-preparation' and 'preparation-to-issue' TAT phases that included: T1; T2; and, T3 (Figure 1).

*Fig. 1*
*Blood delivery journey turnaround time*




## Subjects and Methods

Transfusion audit data can be gathered retrospectively, prospectively or concurrently. Our



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MRN (Pt Name & Corp#)

Date: ……………………………
Operating Room Number: ………..
Name & Corp # of Blood Bank Staff Answered the Phone ……………………………………………

| Surgery | Ph Name On request | Sn | T1 | Blood B Response | No of Units R | Type & Screen | CM | B.C Req | AntiB | T2 | T3 | T4 | No of U.G | No of U.R | Waste |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | |

**OR Anesthesia Tec & Corp #:** ……………………………………
Signature

**Blood's Carrier Name & Corp #:** ………………………………...
Signature

Time of Arrival to Blood Bank: ……
Time of Leaving the Blood Bank:……..

Blood bank Staff Name & Corp #: ………………………………………

Signature: …………………………

**Index:**

| | |
|---|---|
| Sn | Seniority = **1**=Resident / **2**= Specialist / **3**= -Consultant |
| CM | Cross Match |
| AntiB | Antibodies (Yes or No) |
| No of UG | No of units given |
| No of U.R | No of units returned |

| | |
|---|---|
| T1 | Time when Blood Bank was Called |
| T2 | Time when being informed that the blood is ready |
| T3 | Blood Collection Time |
| T4 | Time when the Blood arrived to OR |

*Fig. 2*
*Audit form for reporting blood delivery TAT*

data was prospective, having the advantage of giving the patient the benefit of receiving the appropriate transfusion therapy, whilst allowing for more precise/ accurate information to be gathered for wide audit evaluations[14]. At our institution (Hamad General Hospital, Hamad Medical Corporation, Qatar, 650 bed tertiary hospital), a skilled technologist was trained to use a specially designed audit form for recording Response time (T1), Processing time (T2), and Transport time (T3) (Figure 2). For quality assurance, each of these three times entered was verified by another technician and the blood bank technician who signed against each of the reported times.

At our institution, in planned transfusion, blood products are ordered using an electronic medical record (EMR) system that transmits the order to the blood bank a day before elective surgery. The start time is the time of blood product request by the anesthesiologist (requisition form, step one). The availability of blood and its collection from the blood bank is additionally confirmed by phone in all emergency cases. The preparation time is the time until all lab and matching tests are completed and blood product is ready for collection (step two). A pop-up window notifies nurses and other healthcare professionals when the blood products are ready for issue. Then, a courier collects the blood products from the blood bank and delivers them to the operating suite (step three). We analyzed the total TAT, comprising the sum of T1 + T2 + T3. The findings of the first audit were discussed at our departmental corporate transfusion committee and internally where suggestions (corrective actions taken for risk mitigation) were put forward for improvement of blood delivery TAT that included:

1. Organizational: assigning a Blood bank officer to process the operating theatres' requests as a priority;
2. Educational: multiple education sessions for physicians on optimum use and completion of the blood request on line form, and the differences between type, screen, and cross match requests.
3. Operational: reducing the transport time by assigning this task to a dedicated anesthesia technician.

A second audit was undertaken (November 2017 - December 2017) to evaluate the effects of remedial actions on blood delivery TAT (Figure 2).

## Statistical Analysis

Analysis was undertaken using in SPSS v22 with significance level set at $P < 0.05$. The observed proportions for categorical variables were reported as percentage and compared using Chi square test, and Wilcoxon test and t-test was used for quantitative data.

## Results

We compared the findings of 114 cases of blood requests of the first audit (Baseline, December 2015 - February 2016) to 84 blood requests of the second audit (November 2017 - December 2017). Figure 3 shows the blood bank response time to doctors' requests (T1), with

## Results

We compared the findings of 114 cases of blood requests of the first audit (Baseline, December 2015 - February 2016) to 84 blood requests of the second audit (November 2017 - December 2017). Figure 3 shows the blood bank response time to doctors' requests (T1), with 45% immediate availability for booked blood, 18% availability within one hour, 22% availability within 45 minutes, and 13% within 30 minutes (Figure 3).

Figure 4 illustrates that the processing time at the blood bank (T2) where in 44% it was > 15 minutes, in 33% between 10-15 minutes and in 23% was < 5 minutes.

Figure 5 depicts that the transportation time (T3) was mostly > 15 minutes, with only 10% being transported in < 5 minutes.

The second audit was undertaken (November 2017 - December 2017) to evaluate the effects of remedial actions on blood delivery TAT. Figure 6 shows improvement of blood bank response time, where blood was ready to collect within 30 mins in 36% of requests, compared to 13% in 2016. However, booked blood was immediately available in 36% of patients compared to 45% in 2016.

Figure 7 shows the processing time improvement, where > 50% of requests were processed in < 10 mins after operating theatre requests.

Figure 8 demonstrates the improvement in collection⁄ transport time after assignment of this role to a dedicated technician. In > 90% of cases, the time was < 15 mins compared to 10% in 2016.

## Discussion

Transfusion of blood/blood products is a significant component of hospital services[14], integral to patient management, and a critical element for quality healthcare delivery. Insufficient perfusion secondary to hypovolemia and inadequate oxygen delivery result in major organ damage after very brief periods[15]. The current study is a starting point for establishing TAT benchmark for issuing blood from the blood bank to ORs at our institution.

The American Association of Blood Banks (AABB) defines quality indicators as performance measurements to monitor process/es during a defined time to appraise service demands, production, adequacy, inventory and process stability[16]. In transfusion practice, quality comprises: blood collection centre, transfusion service and clinical practice. Whilst, all such indicators are critical[17], we focused on the transfusion service's dynamics of blood delivery TAT to improve it, in support of evidence-based practice. In the transfusion service, auditing detects waste[18], and successful transfusion service quality improvement advances developments, efficiency, effectiveness, and patient safety by impacting all processes from the transfusion service laboratory to the patient's bedside[19].

The current study implemented multipronged actions as we assigned a blood bank officer to process the OT requests as a priority, educated physicians on use/completion of the blood request form, and reduced transport time by assigning this task to a dedicated anesthesia technician. These collective efforts focused on blood transfusion process and delivery TAT to result in improvements across our processing times, matching the international standards (30-35 mins) of blood delivery turnaround best time that should be targeted[20]. However, blood was immediately available to 36% of our patients in 2017 compared to 45% in 2016, probably due to an internal decision to limit the number of blood products available for transfusion to the updated maximum surgical blood ordering schedule and to previously cross matched blood units (digital crossmatch) which is inconsistent throughout the year. The most important change for us is the improvement in collection transport time after assignment of this role to a dedicated technician. In > 90% of cases, the time was < 15 mins in 2017 compared to 10% in 2016. In addition, our processing time also improved, where in 2017 > 50% of requests were processed in < 10 mins after operating theatre requests, compared to 54% in the 2016 audit. Others confirmed that TAT, defined from receipt of order in the transfusion service until units are available for issue, as routine (8 hours), ASAP (4 hours), and STAT (2 hours)[21].

In terms of the different time 'signatures' that make up the TAT deliver journey, focusing on practices that save time before components are released from

*Fig. 3*
*Baseline response time*

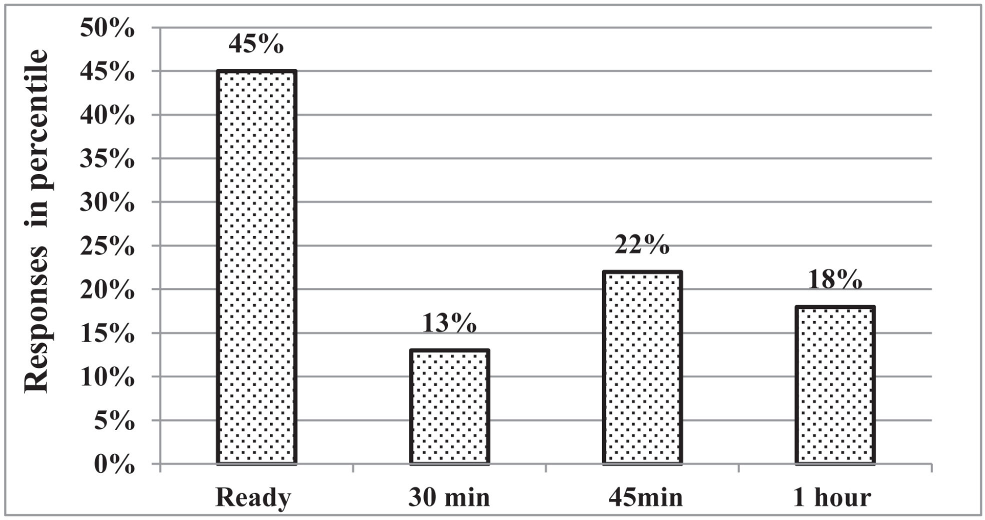



*Fig. 4*
*Baseline processing time (mins)*

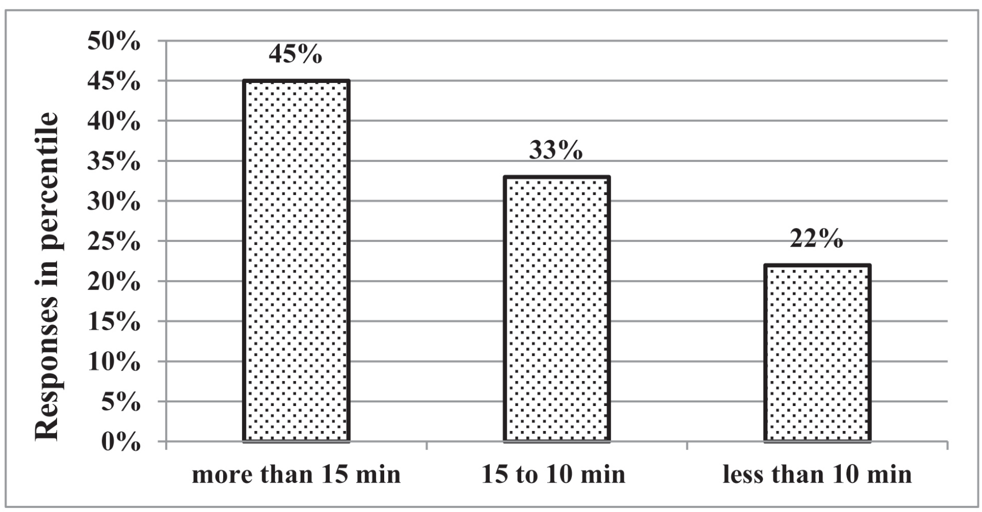



*Fig. 5*
*Baseline Transportation Time (mins)*

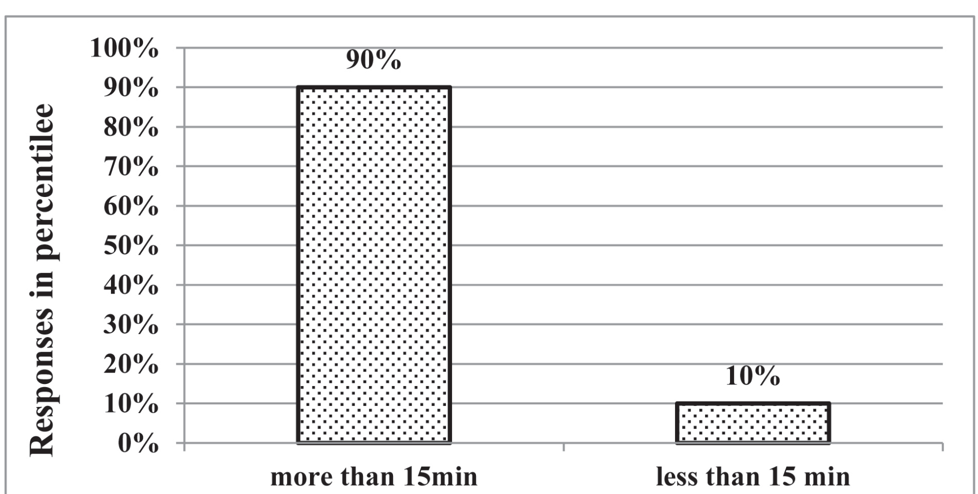


*Fig. 6*
*Response time improvement (min)*

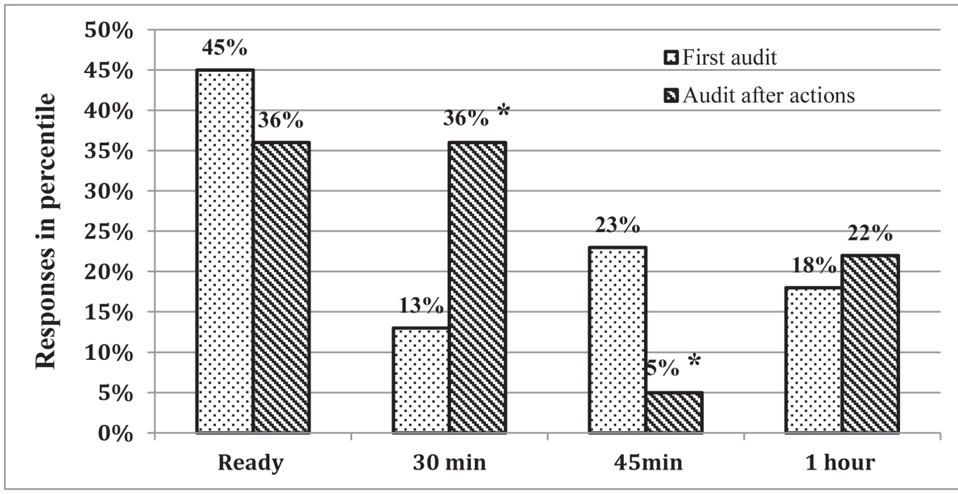



*Fig. 7*
*Processing Time improvement (min)*

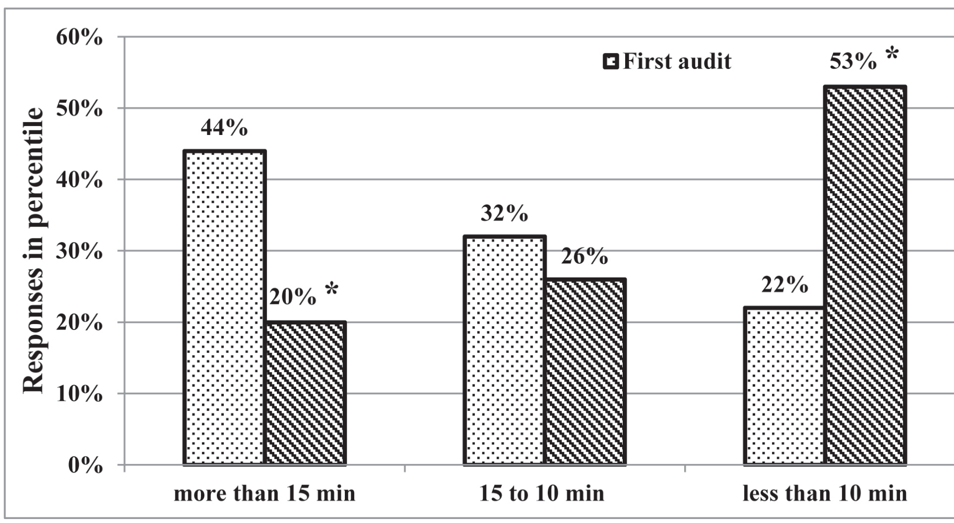
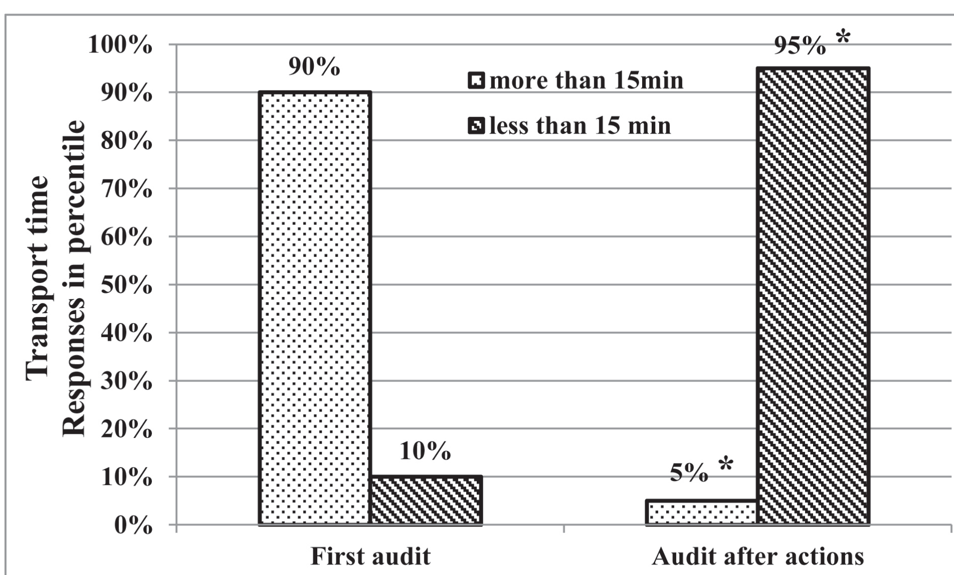



*Fig. 8*
*Transport Time improvement (min)*



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In terms of the different time 'signatures' that make up the TAT deliver journey, focusing on practices that save time before components are released from blood banks is more efficient in reducing overall TAT than practices that save time after components are released from blood banks[20]. We measured three time 'signatures' (response, processing and transport times) in order to pin point trends and causes of TAT delays. However, we did not find other studies that detailed/ itemized such measurements describing the time 'signatures' of the blood transfusion TAT journey.

Hence, we are not able to directly compare our findings with others[10,11]. Future TAT research might benefit from standardization and reporting of such measurements to facilitate direct and unequivocal comparisons between institutions, countries and studies. In India, among 125 cases, 59 (47.2%) of cases had a TAT > 30 minutes[10]. Our TAT, measured at the second audit (33±21 min) is similar when compared to western centers[10,11].

In terms of the definitions of TAT, a point to note is the different TAT definitions, e.g. from time of reception of a request to time at which the blood unit was handed over to attender for transporting it to bedside[10], from time of request to when RBCs exited the blood bank[11], or from receipt of specimens/order in the Transfusion Service until units are available for issue (routine 8 hours, ASAP 4 hours, and STAT 2 hours)[21].

In terms of previous cross matching, others[22] described TAT for a procedure that involved previously cross-matched blood units (digital crossmatch) that needed only issue to OT. Others reported very short TATs when only issuing was involved and compatibility was checked beforehand[23], and still other researchers reduced their time to issue RBCs to 2.5 minutes, but this was only the time to issue and did not include either the time for ABO typing and screening, or time for placement of units in the OT self-service system, both of which had been accomplished earlier[24].

In the current study TAT was calculated from the request time to the time blood is on bedside (theatre) (Figure 1). Our mean TAT decreased from 35±33 min (first audit) to 33±21 min (second audit), and although this mean TAT decrease was not statistically significant ($p = 0.58$), however, some individual TAT components showed significant differences. For instance, our transport time was significantly decreased ($p < 0.0001$) between the first and second audits. Further, although our response time was not significantly changed ($p = 0.95$) between the two audits, nevertheless there was a 50% improvement in 30 mins response time. Likewise, the percentage of requests processed in < 10 mins were significantly higher in the second audit compared to the first one ($p = 0.022$). Future TAT research might benefit from a standardization of such definitions response, processing and, transport times to enable precise and unambiguous comparisons between different institutions, countries and studies.

In the current study, the clinical audit cycle involves gauging care against explicit criteria, taking action to improve it if required, and monitoring the process to maintain improvement, where as the process continues, greater quality level is attained. Based on our initial TAT findings, we analyzed the causes and implemented remedial actions for risk mitigation for 3 months, aiming to shorten the blood delivery TAT. Then we assessed the same three TAT blood delivery indices again (November 2017 - December 2017) to judge whether our actions were generating the desired goals. In line with others[14], we started with an uncomplicated approach, acknowledged the shortcomings, while generating a philosophy of advancement and a culture of continuous improvement.

The current study contributes to the sparse literature on blood delivery TAT and interventions that aim to shorten TAT for efficient blood delivery. The current study could be the first Middle East North Africa to assess blood delivery TAT, implement corrective actions (risk mitigation), and re-measure the same TAT indices to assess improvement (2017 vs. 2016). Such research is high priority for the international field of transfusion medicine to improve the evidence base for hemotherapy.

Finally, in terms of the type of product, i.e. whether the TAT is for blood or for one/some its components, a related point is the component/s that TAT is measured for. We measured TAT only for whole blood requests. Other studies measured it for either single components e.g. TAT of issuing red blood cells (RBCs)[11] or for multiple components e.g. packed red cells (PRC), fresh frozen plasma (FFP) and platelet concentrates (PC)[10].

## Conclusions

Anecdotal evidence suggests that many institutions do not monitor blood delivery (TAT) as a quality indicator. At our institution, blood delivery TAT from the Blood bank to OR was much improved after implementing a multipronged quality improvement approach. Our program and its implementation findings represent an appropriate and effective solution to the challenge of making blood available fast enough to meet true hemorrhagic emergencies.

## References


1. Lier H, Bernhard M, Hossfeld B: Hypovolemic and hemorrhagic shock. *Anaesthesist*; 2018, 67(3):225-44.
2. Lee A-J, Kim S-G: Analysis of turnaround time for intraoperative red blood cell issues: A Single-Center Study. *Lab Med*; 2017, 48:277-81.
3. Heier H, Sorlie D, Soreide E, Bugge W, Hjelmeland K, HaHeim LL: Tranfusion and alternative technologies. Report from Kunnskapssenteret no. 8-2005. Oslo: Norwegian Knowledge Centre for the Health Services, 2005.
4. Whitaker B, Rajbhandary S, Kleinman S, Harris A, Kamani N: Trends in United States blood collection and transfusion: results from the 2013 AABB Blood Collection, Utilization, and Patient Blood Management Survey. *Transfusion*; 2016, 56(9):2173-83.
5. Repine Tb, Perkins Jg, Kauvar Ds, Black- Borne L: The use of fresh whole blood in massive transfusion. *J Trauma*; 2006, 60(6):59-69.
6. Javaudin O, Baillon A, Varin N, Martinaud C, Pouget T, Civadier C, Clavier B, Sailliol A: Air-drop blood supply in the French Army. *J R Army Med Corps;* 2018, 164(4):240-44.
7. Holcomb Jb: Transport Time and Preoperating Room Hemostatic Interventions Are Important: Improving Outcomes After Severe Truncal Injury. *Crit Care Med*; 2018, 46(3):447-453.
8. Stokes Ea, Wordsworth S, Staves J, Mundy N, Skelly J, Radford K, Stanworth Sj: Accurate costs of blood transfusion: a microcosting of administering blood products in the United Kingdom National Health Service. *Transfusion*; 2018, 58(4):846-53.
9. Burgmeier Jrn: Failure Mode and Effect Analysis: An Application in Reducing Risk in Blood Transfusion. *Jt Comm J Qual Improv*; 2002, 28(6):331-39.
10. Ramanathan T, Shaiji PS, KC Usha: Turnaround time for issuing blood products in emergency-a prospective real time study in a regional blood transfusion centre. *IJCMR*; 2017, 4(3):688-91.
11. Mcclain Cm, Hughes J, Andrews JC, Blackburn J, Sephel S, France D, Viele M, Goodnough LT, Young PP: Blood ordering from the operating room: turnaround time as a quality indicator. *Transfusion*; 2013, 53:41-8.
12. Yazer MH, Lozano M, Fung M, Kutner J, Murphy MF, Oveland Apelseth T, Poglod R, Selleng K, Tinmouth A, Wendel S, Yahalom V: and on behalf of the Biomedical Excellence for Safer Transfusion (BEST) Collaborative. An international survey on the role of the hospital transfusion committee. *Transfusion*; 2017, 57:1280-87.
13. Vollmer Rt: Analysis of Turnaround Times in Pathology. *Am J Clin Pathol*; 2006, 126:215-220.
14. Nel TJ: Clinical guidelines, audits and hemovigilance in managing blood transfusion needs. *Transfus Altern Transfus Med*; 2008, 10:61-69.
15. Basu S, Liu X, Nozari A, Rubertsson S, Miclescu A, Wiklund L: Evidence for time-dependent maximum increase of free radical damage and eicosanoid formation in the brain as related to duration of cardiac arrest and cardio-pulmonary resuscitation. *Free Radical Res*; 2003, 37:251-256.
16. Roback JD, Grossman BJ, Harris T, Hillyer CD: Ed. Technical Manual, 17th edition, American Association of Blood Banks, Bethesda, Maryland, 2011, p. 24.
17. World Health Organization: Safe blood and blood products: indicators and quality of care. World Health Organization, Regional office for the western Pacific, Manila, Philippines. October 1996.
18. Yazer MH: Auditing as a means of detecting waste. *VOXS*; 2018, 13:29-34.
19. Goodnough LT, Viele M, Fontaine M, Chua L, Ferrer Z, Jurado C, Quach P, Dunlap M, Arber, DA: Quality management in the transfusion service: case studies in process improvement. *Transfusion*; 2011, 51:600-09.
20. Novis DA, Friedberg RC, Renner SW, Meier FA, Walsh MK: Operating room blood delivery turnaround time: a College of American Pathologists Q-Probe Study of 12647 units of blood components in 466 institutions. *Arch Pathol Lab Med*; 2002, 126(8):909-14.
21. Inland Northwest Blood Center: 2014 annual report. 2014 Inland Northwest Blood Center: Spokane, Washington, USA.
22. Weiskopf RB, Webb M, Stangle D, Klinbergs G, Toy PA: Procedure for Rapid Issue of Red Cells for Emergency Use. *Arch Pathol Lab Med*; 2005, 129:492-96.
23. Cox C, Enno A, Deveridge S: Remote electronic blood release system. *Transfusion*; 1997, 37:960-64.
24. Cheng G, Chiu DS, Chung AS, et al: A novel system for providing compatible blood to patients during surgery: "self-service" electronic blood banking by nursing staff. *Transfusion*; 1996, 36:347-50.