

Use of automation to reduce error in sample preparation

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Background

Efforts to reduce preanalytical laboratory errors have historically focused on improved training, auditing compliance with specimen collection procedures, and establishing metrics to quantify the errors¹. While these methods have demonstrated substantial reductions in error rates, preanalytical error during manual processes remains the top source of error in laboratories worldwide². Furthermore, many preanalytical errors are undetectable in practice³, thus increasing the risk that inaccurate test results are used for clinical decision-making.

This work describes the use of automation to address the root cause of errors during sample preparation by eliminating manual processes, reducing the potential for human error, and improving detectability of residual errors during the preanalytical phase. We explore four sample preparation processes that are prone to human error—identification, mixing, centrifugation, and refrigeration—and methods for automating each that are implemented in the Babson Sample Preparation Device, a preanalytical device used in the BetterWay blood testing service. The Babson Sample Preparation Device works together with the BD MiniDraw tube to standardize collection and preparation of capillary blood. The device also monitors these processes and alerts the laboratory if an error has occurred. We discuss a case study examining rates of error in sample preparation when using these technologies.



Methods & Results

We reviewed a cohort of 1,000 patient sample collections using the Babson Sample Preparation Device and the BD MiniDraw from April 12 to June 17, 2025. The rates of error in sample identification, mixing, centrifugation, and refrigeration were 0.0%, 0.0%, 0.5%, and 0.2%, respectively.

Identification

Prior to collection, the operator begins by scanning their badge and the patient's visit code (unique order identifier). After verbally confirming the patient's name and date of birth, the operator scans the patient's photo ID or enters their date of birth, which the system verifies as correct for the order. LED lights display the correct tube type(s) and the draw order. The operator scans the manufacturer-applied barcode on the empty BD MiniDraw tube; the system verifies it is the correct type. Once the collected sample is deposited into the device, the system rescans it and digitally links the specimen with the order, the patient's name and date of birth, the identity of the operator, and the date and time of collection.

Identification errors were observed in 0 of the 1,000 collections. The paperless system avoids errors related to adhesive labels and provides strong safeguards against misidentifying the specimen, patient, operator, and collection date and time.

Centrifugation

After mixing, serum separator tubes are stored at ambient temperature to clot for 45 minutes (or up to 120 minutes if a backlog of tubes await centrifugation), then are automatically transferred into a swing bucket centrifuge that processes one sample at a time. The centrifuge accelerates on a predefined ramp up to 4,000 g for 135 seconds, then decelerates quickly, as is appropriate for BD MiniDraw SST tubes. The centrifuge is driven by a variable frequency drive motor and controller with two hall effect sensors, which allow the system to continuously monitor the centrifuge speed, report any errors, and shut down in case of a safety issue.

Centrifugation errors were observed in 5 of the 1,000 collections, 3 due to tube jams from an issue with the software version in use at the time, and 2 due to human error from the portable component being left undocked by the operator for over 120 minutes.

Mixing

When a collected sample is deposited into the device, its manufacturer-applied barcode identifies the mixing profile for the tube type. A mixing arm controlled by a stepper motor inverts the tube the correct number of times by rotating it between 5° and 175° around an axis, with controlled acceleration, speed, and deceleration. Timestamps are recorded for the deposit and the start and end of mixing. If the mixing profile is not completed accurately, the device reports the error and is able to retry.

Mixing errors were observed in 0 of the 1,000 collections. Automated mixing prevents skipped or incorrect mixing due to human error, though an undetectable timing error may still occur if sample deposit is delayed.

Refrigeration

After processing, samples are automatically transferred into a refrigerated chamber. Temperature is maintained at 2–8°C by two cooling bricks containing phase change material with a freezing point of ~4°C. The bricks are similar to ice packs, but their higher freezing point reduces the risk of accidental sample freezing. The bricks are rated to maintain the required temperature range for up to 48 hours and are typically replaced every 24 hours. During storage and transport to the laboratory, an RFID tag continuously logs the temperature; at the lab, the courier downloads the temperature data.

Refrigeration errors were observed in 2 of the 1,000 collections, both due to a mechanical malfunction that prevented transferring the samples into the refrigerated chamber, which has since been mitigated through software and hardware upgrades.

Conclusions

This case study demonstrates the potential for automation to address the root causes of sample preparation errors that occur in the preanalytical phase. Automated systems can significantly minimize or eliminate sources of human error while also adding monitoring functions to alert the laboratory if a sample has been compromised and should not be tested. Significant opportunity remains for future innovations in automation to further reduce preanalytical error. One limitation of the Babson Sample Preparation Device is that it is intended for use with capillary blood; introduction of similar systems intended for use with venous blood could greatly expand the reach of its benefits. While it is not possible to fully quantify the impact of automation, it is clear that automated technologies can both reduce the risk of human error and improve detectability of any residual error.

References 1. Plebani M. Quality indicators to detect pre-analytical errors in laboratory testing. *Clin Biochem Rev*. 2012 Aug; 33(3):85–88. 2. Mrazek C, Lippi G, Keppel MH, Felder TK, Oberkofler H, Haschke-Becher E, Cadamuro J. Errors within the total laboratory testing process, from test selection to medical decision-making: a review of causes, consequences, surveillance and solutions. *Biochem Med (Zagreb)*. 2020;30(2):020502. doi:10.11613/BM.2020.020502. 3. Bonini P, Plebani M, Ceriotti F, Rubboli F. Errors in Laboratory Medicine. *Clin Chem* 2002;48(5):691–8.