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Impact of Daylight Saving Time on the Clinical Laboratory

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Abstract

Daylight saving time is a practice in some countries and local regions to set clocks forward (typically 1 hour) during the longer days of summer and back again in autumn. Time changes resulting from daylight saving time have the potential to impact clinical laboratory instruments, computer interfaces, and information systems. We analyzed turnaround time data for an academic medical center clinical laboratories (chemistry, hematology, blood gas analyzer, and transfusion medicine), examining how turnaround time was impacted by the daylight saving time shifts in 2017. We also determined whether the daylight saving time shift on November 5, 2017 ("fall back" by 1 hour) resulted in any "absurd" time combinations such as a receipt time occurring "before" a normally later time such as final result. We also describe challenges resulting from daylight saving time changes over a 5-year period. The only significant impact on turnaround time was for clinical chemistry samples during the autumn daylight saving time change, but the overall impact was low. Four instances of absurd time combinations occurred in the autumn time change with only a transfusion medicine example resulting in an interface error (a Type and Screen resulted "before" receipt in laboratory). Over a 5-year period, other daylight saving time impacts included problems of reestablishing interface to instruments, inadvertent discrepancies in manual time changes at different points of the core laboratory automation line, and time change errors in instruments with older operating systems lacking patches that updated daylight saving time rules after 2007. Clinical laboratories should be aware that rare problems may occur due to issues with daylight saving time changes.

Keywords

clinical chemistry tests, clinical laboratory information system, electronic health record, hematology, software, transfusion medicine

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Introduction

Daylight saving time (DST) is a practice in some countries and local regions to set clocks forward (typically 1 hour) during the longer days of summer and back again in autumn. DST has a long and complicated history worldwide, including regions where DST was adopted and then later repealed.[1-4] In the United States, the majority of states and territories have adopted DST, with the major federal legislation being the Uniform Time Act of 1966.[1,2,5,6] Current exceptions in the United States include Arizona (except for the Navajo on tribal lands), Hawaii, and the overseas territories of American Samoa, Guam, Puerto Rico, Northern Mariana Islands, and the US Virgin Islands. Arizona observed DST starting in 1967 as part of the Uniform Time Act but then exerted an exemption statute and opted out of DST in 1968. Most of the state of Indiana did

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not observe DST until 2006. In the United States, DST starts on the second Sunday in March (spring forward) and ends on the first Sunday in November (fall back), with the time changes at 2:00 AM local time. This means that the time officially jumps from 2:00 AM to 3:00 AM on the spring date and back from 2:00 AM to 1:00 AM on the autumn date.

There is relatively little published literature on the impact of DST changes in health care, with the major focus being on accidents,[7-12] myocardial infarction risk,[13,14] mood disorders,[15] and sleep disruption.[16] Two studies have shown a small but transient impact of DST shifts on the incidence and timing of myocardial infarction, with elevated risk during the spring shift and lower risk in the autumn change.[13,14] Multiple studies have shown increases in motor vehicle and/or other accidents following the spring shift, also with elevated risk in the spring.[7-9,11] However, other studies have not seen a significant effect.[10,12] The DST impact on myocardial infarction and accidents may be related to the loss of sleep during the spring shift and an extra hour of sleep during the autumn shift. Impacts of DST changes on mood disorders have also been reported.[15]

There has been little investigation on DST impact on instrumentation and devices used in health care. A review article on technical issues that may affect insulin pumps covered potential glitches associated with DST changes.[17] These include lack of automatic adjustment and global positioning system capability of some devices. Manual changing of time on insulin pumps carries risks such as inadvertent confusion between AM and PM (for devices not using military or 24-hour time) or adjustment of time in the wrong direction for a DST shift. In the case of insulin pumps, erroneous time could lead to improper timing of insulin delivery. The risks with insulin pumps could equally well impact a variety of medical devices and instrumentation that depend on accurate time for their function yet have varying capabilities for the DST adjustment.

Within clinical laboratories, DST changes can have a number of impacts. First, depending on instrument and computer capabilities, performing the time change itself may require shutdowns or pauses that impact specimen processing and analysis, potentially requiring additional manual staff effort and delaying turnaround times (TATs). Second, times associated with specimens (eg, order time, collection time, receipt time, and result time) will be affected if the DST change occurs somewhere in the specimen history. This may have negligible impact for most specimens but can potentially result in problems such as "absurd" times (eg, result time occurring "before" receipt time in the autumn change) or complicate the interpretation of laboratory tests where timing may be especially important (eg, therapeutic drug levels and associated medication administration times; or Type and Screen results relative to blood product release). Lastly, the DST change may inadvertently be adjusted in the wrong direction, either due to manual error or software glitch.

In this report, we evaluate the impact of DST changes on the operations of clinical laboratories within an academic medical center. This analysis was originally prompted by DST-related technical problems within the core laboratories that ultimately led to a more detailed protocol for handling the DST shifts. Our analysis included assessment of the number and type of specimens impacted by the spring and autumn time changes and of problems resulting from the DST changes.

Material and Methods

Institutional Setting

The institution of this study, University of Iowa Hospitals and Clinics (UIHC), is a 761 bed state academic medical center that serves as a regional tertiary/quaternary care center with a full range of pediatric and adult inpatient and outpatient services, including intensive care units. The electronic health record (EHR) for UIHC has been Epic (EpicCare Ambulatory and EpicCare Inpatient version Hyperspace 2017, Madison, Wisconsin) since May 2009. The laboratory information system (LIS) for all UIHC clinical laboratories is Epic Beaker (version Hyperspace 2017), with Beaker Clinical Pathology and Anatomic Pathology (AP) implemented in 2014 and 2015, respectively.[18,19] Interfacing of laboratory instruments to the LIS is mostly via middleware software (Instrument Manager, Data Innovations, Burlington, Vermont).[19,20] The core laboratory has a Roche Diagnostics (Indianapolis, Indiana) automated line (8100) that connects to 10 cobas 8000 chemistry analyzers and 2 Sysmex XN series hematology analyzers. The Roche chemistry analyzers were upgraded from modular P (photometric and ion-selective electrode) and E170 (immunoassay) analyzers to the cobas 8000 series of analyzers in February 2013. The 8100 automated line replaced the MPA-7 preanalytical line in January 2017. The introduction of the 8100 line also included the hematology (Sysmex, Lincolnshire, Illinois) analyzers, which were formerly separate from the process of the chemistry analyzers. The transfusion medicine LIS for the UIHC DeGowin Blood Center utilizes software from Haemonetics (Braintree, Massachusetts).

The core laboratory (chemistry and hematology) runs approximately 3 500 000 tests annually. The DeGowin Blood Center issues approximately 1300 packed red blood cell, 4200 plasma, and 4100 platelet units per year. The Blood Center also includes pheresis and tissue bank services.

Analysis

Data in this report were collected as part of a retrospective study approved by the University of Iowa Institutional Review Board (protocol # 201801719) covering the time period from January 1, 2012, to December 31, 2017. This study was carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki). As previously described,[21,22] Epic Reporting Workbench was used to retrieve order descriptions, order and result date/times, patient demographics, patient location, and results for clinical laboratory testing. The analysis also utilized preexisting TAT and specimen tracking reports from Healthcare Enterprise Decision Intelligence, a data warehouse managed by UIHC hospital information technology (Health Care Information Systems).[23]

Table 1. UIHC Core Laboratory and Transfusion Medicine Instruments and Interfaces.

Manufacturer	Model	Quantity	Method of Time Change	Comments
Advanced Instruments	A2O Osmometer	1	Manual	
Bio-Rad	BioPlex 2200	2	Automatic	
CellaVision	DM96	2	Automatic	• Nearly 5-hour downtime in 2017 autumn DST change due to loss of connectivity with middleware
Data Innovations	Instrument Manager version 8.13	1	Manual	• Cache database requiring manual time change and then restart • Instruments may have difficulty regaining conductivity
Immucor	Echo	2	Manual	• Uses Windows XP without patches and updated DST dates post-2007 (vendor restriction)
Radiometer	ABL 90	4	Automatic	• If auto-update fails, troubleshooting deferred until dayshift
Roche	Cobas c502, c602, c702	3, 4, 2	Manual	• Analyzers must be in standby mode with samples cleared out
Roche	Cobas p701 post-analytical storage	1	Automatic	
Roche	8100	1	Manual	• Must be cleared out prior to time change • Samples remaining in system will error out
Siemens	BCS XP	2	Manual	• Extended downtime in previous years following time change
Sysmex	XN series	1	Automatic	• Manual process for time change is quite involved if auto-update fails

Abbreviations: UIHC, University of Iowa Hospitals and Clinics; DST, daylight saving time.

With regard to issues that occurred during DST changes, e-mails and variance reports were reviewed for DST changes in 2012–2017. The analysis focused on core laboratory (chemistry, hematology, blood gas analyzers) and transfusion medicine. AP was not included, since the AP laboratory is not open during the hours spanning the time change. Microbiology and molecular pathology were also not included due to very light volume of test resulting during the hours spanning the time change. The analyzers and interfaces potentially most impacted by DST changes are listed in Table 1, which also includes comments on DST-related issues. Table 2 summarizes the overview of the core laboratory staff protocol for the DST changes. The current protocol has been adapted multiple times over the past 5 years to address challenges during previous DST changes.

Detailed analysis on TAT and time stamps (eg, receipt time, result time) covered in this report cover the DST shifts in 2017 only, when these times could be reliably extracted. For automated instrument analysis, tests potentially most affected by DST changes were defined as those with receipt times in the laboratory within 2 hours before and 2 hours after the time changes (4 hours total). The TAT analysis examined this 4-hour period compared to the entire day. For the autumn time change, "absurd" time combinations were those where a normally later time appeared "before" a normally earlier time (eg, result time before receipt time). The March 12 and November 5 DST change dates in 2017 were compared to the other Sundays in March and November of that year. For the non-DST Sundays in March and November, 0:00 to 04:00 was the time period that was used to correspond with the DST Sundays. Statistical analysis was conducted using Student *t* test.

Table 2. Timeline for Time Change Tasks at UIHC.

Approximate Time (Unadjusted for DST Change)	Tasks
01:30-01:45	Hospital IT contacts laboratory
01:45	Stop loading 8100 automation line and clear out specimens
	Log off middleware terminals
02:00-02:30	Cycle middleware to adjust times (typically takes less than 10 minutes)
	Change time on data manager and then control units for chemistry analyzers; verify that times are synced
	Change time on other instruments requiring manual adjustment
02:30-02:45	Check instrument connections
	May need to reset middleware interfaces
	Contact technical support for any problems
	Touch base with hospital IT
02:45	Troubleshoot problems

Abbreviations: UIHC, University of Iowa Hospitals and Clinics; DST, daylight saving time.

Results

Impact of Daylight Saving Time on Automated Testing Turnaround Time and Time Stamps

We focused detailed TAT analysis on the potential impact of DST shifts using data from 2017. The core laboratory has an automation line that links to the main chemistry and hematology analyzers and performs preanalytical functions, such as centrifugation and aliquoting. The core laboratory also includes a Critical Care Laboratory section that performs analysis on

blood gas analyzers for whole blood specimens. This is not connected to the automated line.

The TATs for clinical chemistry, hematology, and blood gas analyzer analysis are presented in Figure 1. The data include all Sundays in March 2017 and in November 2017, with TAT separated into 2 categories: specimens with receipt times within the 4 hours bracketing the time change (0:00-04:00 in non-DST Sundays) and for the entire day for each Sunday. Table 3 summarizes the number of tests during the days of analysis. As can be seen in Figure 1, the only significant impact on TAT was for clinical chemistry samples during the autumn time change (November 5, 2017). Both hematology and blood gas analyzer analysis had slightly higher average TAT during the 0:00 to 04:00 time period compared to other Sundays but did not reach statistical significance. The standard deviation of the TAT for the hematology and blood gas analyzer analysis was wider than in corresponding Sundays, driven by a small number of samples with extended TAT related to interface resulting issues following the DST change. Manual differentials were used as a backup for samples whose automated differential could not cross the interface. Overall, the impact of DST was only evident in the early morning times and did not impact average TAT for the entire day.

We also analyzed whether the DST changes resulted in any "absurd" time combinations. The only absurd combinations were noted during the autumn DST change (November 5, 2017), with 2 chemistry and 1 hematology test result each having a result time "before" receipt time in the laboratory. None of the 3 results ended up with the result time being before the specimen collect or provider order time in the EHR. There appeared to be no clinical impact for these 3 results.

The spring 2017 DST change causes no reported issues in transfusion medicine. The November 2017 DST change resulted in a single absurd case of a Type and Screen result occurring "before" receipt in laboratory. This situation caused an interface error from the Haemonetics SafeTrace Tx (transfusion medicine LIS) to the EHR and required manual intervention to post the result in the EHR. The only blood products issued by the UIHC Blood Center in the immediate time around the autumn 2017 DST change were 2 packed red blood cell units released at 01:12 after the fall back in time. These were released without incident.

Daylight Saving Time -Related Issues in Earlier Years

Review of data from 2012 to 2016 revealed some other issues associated with DST changes. In general, it was the autumn shift (fall back) that created more issues. In 2016, the core laboratory coagulation analyzers (Siemens BCS, Lincolnshire, Illinois) had difficulty interfacing back with the middleware system following the manual instrument time change, even after multiple restarts. The analyzers were operational after the manual time change, but interface took several hours to be reestablished. This caused TAT delays in coagulation test resulting.

In earlier years, more challenging DST issues have arisen at various points in the middleware interface and automated line.

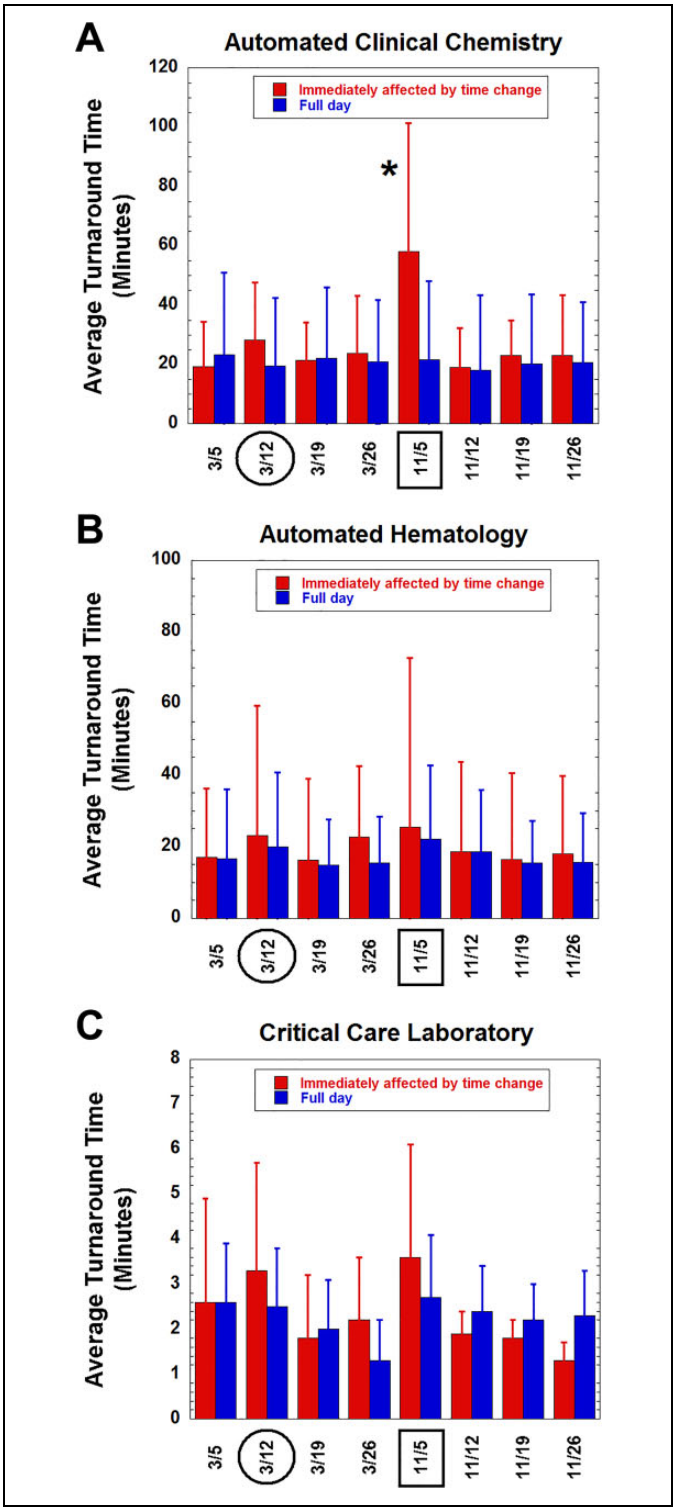

Figure 1. Turnaround time (TAT) for clinical chemistry (A), hematology (B), and critical care laboratory (C) testing during Sundays in March and November 2017. TAT was calculated as from receipt in laboratory to final result. For each date, the first bar (in red) is for the 2 hours before and 2 hours after DST shift and for 0:00 to 04:00 for the other 6 Sundays. For each date, the second bar (in blue) is for the entire day. The only significant difference in TAT is on November 5 for clinical chemistry tests for the hours immediately bracketing the DST change (labeled with *, $P < .01$). DST indicates daylight saving time.

Table 3. Automated Testing Volumes for Sundays in March and November 2017.

Date	Clinical Chemistry*		Hematology*		Critical Care Laboratory*	
	0:00-04:00	All Day	0:00-04:00	All Day	0:00-04:00	All Day
March 5	96 (4.2%)	2276	59 (5.0%)	1173	21 (5.6%)	376
March 12[†]	102 (3.9%)	2634	55 (4.4%)	1248	15 (4.2%)	355
March 19	79 (3.1%)	2517	53 (4.4%)	1198	14 (3.8%)	364
March 26	69 (3.3%)	2088	47 (4.2%)	1132	19 (5.0%)	378
November 5[†]	107 (4.5%)[‡]	2357	65 (5.0%)[‡]	1295	23 (6.4%)	362
November 12	92 (3.7%)	2470	51 (3.6%)	1417	16 (4.2%)	377
November 19	82 (3.5%)	2321	54 (4.6%)	1172	14 (4.0%)	348
November 26	60 (2.9%)	2055	46 (3.8%)	1198	12 (4.0%)	300

*Values indicate number of tests in the specified time periods, either 0:00 to 04:00 for non-DST Sundays (or the 2 hours before and after DST change for March 12 and November 5) or all day. The percentage for the 0:00 to 04:00 data column is the percent of total samples in that time window to the volume for the entire day. Clinical chemistry includes automated serologies. Hematology includes blood counts and nonbatched coagulation testing (eg, prothrombin and partial thromboplastin times). Critical Care Laboratory includes analysis of whole blood specimens on blood gas analyzers.

[†]In 2017, March 12 and November 5 were the DST dates in the United States.

[‡]Two chemistry tests and 1 hematology test had "absurd" combination of result time before receipt time.

In 1 case, a staff member attempting a time change on a control unit for the automated line entered an incorrect password too many times, causing system lockout. This caused extended delay in bringing the full automated system back online as resolution required vendor technical support by telephone. In another case, the spring DST change for the automated line front-end (Roche MPA-7 at that time) was inadvertently overlooked, causing time discrepancies between the preanalytical times and those on the downstream chemistry analyzers. The end effect was that the analyzers showed the correct time that was an hour discordant with the (unchanged) preanalytical receipt time, causing a large number of tests to show up erroneously on the overdue list for TAT. Fortunately, the issues encountered still allowed for manual resulting of testing, if needed.

A recurring challenge at UIHC has been analyzers connected to computers with older operating systems, such as Windows XP. Due to vendor restrictions on operating system updates and patches, some computers have out-of-date rules for DST in United States, not incorporating changes to dates put into law 2007. This can lead to an incorrect time change (on the wrong date based on pre-2007 DST dates) or erroneous change back of a valid time change driven by an external standard such as Atomic Clock, examples of which were encountered during the past 5 years. This issue will fade as operating systems get updated with current DST rules.

Table 4 summarizes the types of issues encountered with DST shifts.

Discussion

There is very little literature on the impact of DST on operations within health care. Most focus has been on the impact of DST shifts on accidents, mood disorders, and sleep.[7-16] A review article on technical issues potentially affecting insulin pumps did discuss glitches associated with DST changes that could similarly affect other devices and instrumentation within health care.[17]

Clinical laboratories are a setting where DST changes in time can create problems, with the most obvious impact being on clinical laboratories that operate during the night shift. As illustrated in our own analysis at an academic medical center core clinical laboratory, the methods of changing time for DST shifts vary between analyzers, automation line, and interface software. Some systems change date automatically, while others require manual intervention, in some cases requiring instrument pause or reset prior to time change. Manual time changes may require staff to interact with computer logins or menus on control units or analyzers that they would otherwise not routinely deal with. In addition, problems can occur even for analyzers that change date automatically if there is a discrepancy between the analyzer time and that of the automation line or interface software. Laboratory computers with unpatched older operating systems due to vendor restrictions (eg, the now unsupported Windows XP operating system) may have out-of-date DST rules in addition to their other security risk (sometimes necessitating measures such as strict firewalls). As we outlined above, we have encountered DST issues arising from all of these factors at various times.

Interfaces between the EHR and LIS present an additional complexity in DST changes. The institution in this report (UIHC) utilizes an integrated EHR-LIS system (Epic Beaker Version Hyperspace 2017) that has a common method for time change for the EHR and LIS software. Other institutions with separate EHR and LIS can encounter time change issues related to EHR–LIS interface(s).

One broad issue raised by the challenges in DST changes is the role of manufacturers and regulatory bodies in defining standardized practices and protocols for management of time for clinical laboratory analyzers, interfaces, and information systems. In theory, automated time switches following a consistent standard could streamline the process of managing DST shifts. However, as seen in our retrospective review, some of the most challenging problems resulted when automated DST shifts did not go as planned, in some cases resulting in troubleshooting deferred until dayshift because of cumbersome

Table 4. Types of Issues Encountered.

Issue	Challenges and Considerations
Analyzers/ computers with older operating systems	• Operating system such as Windows XP unable to be patched due to vendor restrictions may lack current DST change roles (eg, 2007 change in US law) • Inaccurate time change can occur with conflict between external time standards (eg, Atomic clocks) that sync system time but then erroneously corrected by out-of-date operating systems perceiving time is incorrect
Cache databases	• Require instrument/computer pause, manual time change, and then restart
"Fall back" issues	• Possible for "absurd" timing (eg, "result" time to be before "received" time) that may cause errors • Extra hour of time needs to be covered by laboratory personnel • One additional hour to prepare for workload from inpatient phlebotomy
"Spring forward" issues	• Generally fewer issues and without risk for absurd timing (unless time change done in incorrect direction) • Jump in time means 1 less hour to prepare for morning inpatient phlebotomy rush • Staff works 1 fewer hour (does this affect pay for that shift?)
Staffing	• Time change occurs on third shift with low staffing • May encounter unexpected challenges (eg, unfamiliar with how to access systems normally perpetually logged in; inadvertent lockout to software access) • Manual time updates compete with other tasks
Syncing issues	• Failure to sync analyzer and automation line times can lead to wrong turnaround times (eg, samples showing up erroneously as overdue)
Transfusion medicine	• Errors in timings of compatibility testing (eg, Type and Screen result before specimen receipt resulting in interface error) • Confusion in blood product distribution and administration time if time change intervenes

manual backup processes (Table 1). The variability in computer operating systems described above adds an additional layer of complexity.

In addition to time discrepancies between instruments and interface software, the autumn DST change (fall back) has the additional risk of absurd time combinations, such as a result time being "before" receipt time. In 2017, we documented 4 occurrences of this (3 in core laboratory, 1 in blood bank), with only the blood bank Type and Screen time discrepancy resulting in an interface error blocking result transmission to the EHR. In our laboratory, the number of absurd time combinations is limited by holding some specimens that arrive just prior to the DST change (especially since the automation line and analyzer are already in pause mode and not able to load new specimens).

In the United States, DST shifts occur on early Sunday mornings (02:00) in March and November. For clinical laboratories associated with hospitals or medical centers, the DST changes would generally fall within the third shift for personnel and also at a time of low specimen volume, being after most late evening inpatient draws and typically before routine morning phlebotomy draws start. For transfusion medicine, the DST changes also typically occur when there is low activity for blood products, being well outside routine surgery hours.

Although the autumn DST change may cause unique problems such as absurd time combinations and an extra hour of work, the fall back in time does allow the staff an additional hour before heavier specimen load arrives (eg, morning inpatient phlebotomy). In contrast, the spring DST change results in a lost hour, with less time to resolve problems before daytime. Human resource issues also arise with the DST changes. For example, does the extra hour during the autumn DST shift garner overtime pay for that additional hour or the regular hourly rate? Conversely, how is compensation handled for the spring DST change which results in 1 less hour of actual work?

Overall, low activity in early Sunday morning hours in the clinical laboratories and blood bank mitigate the impact of DST changes on clinical laboratory service. In the present study, the impacts on TAT for core laboratory were either negligible or apparent for only the hours immediately bracketing the DST change. The occurrence of DST changes on the third shift does raise some potential challenges when problems occur. For most clinical laboratories, early Sunday mornings may be a time of light staffing, possibly without supervisory staff being routinely present or covering multiple laboratory sections. Exceptions may include regional or national reference laboratories that encounter higher specimen volumes from courier deliveries in the evening or intentionally balance high test volumes across all 3 shifts and thus have a greater depth of personnel during the third shift. Early Sunday morning may also be a time when it can be difficult to get through to vendor support for problems that occur. At our institution, a hospital IT representative checks in with the laboratory prior to the time change and is available to coordinate if any problems occur. We have strengthened our protocol for DST changes over the years to account for previous issues.

In summary, DST can affect clinical laboratories, especially with the November fall back in time, but with a generally small impact due to low volumes of specimen testing on early Sunday mornings. Clinical laboratories should be aware that rare problems may occur due to issues with DST changes.

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