



Neither Heat, Nor Snow, Nor Gravitational Force: The Effect of Specimen Transport Conditions on Clinical Laboratory Testing



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Service Line Medical Director, VUMC Core Laboratory

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 @DxSteward

Disclosures for Joe Wiencek, Ph.D.

I have the relationships with:

- Consultant Fees: Roche Diagnostics
- Funding (Honorarium): AACC
- Travel Support: AACC, ASCP

Learning Objectives

At the conclusion of this presentation, learners will be able to...

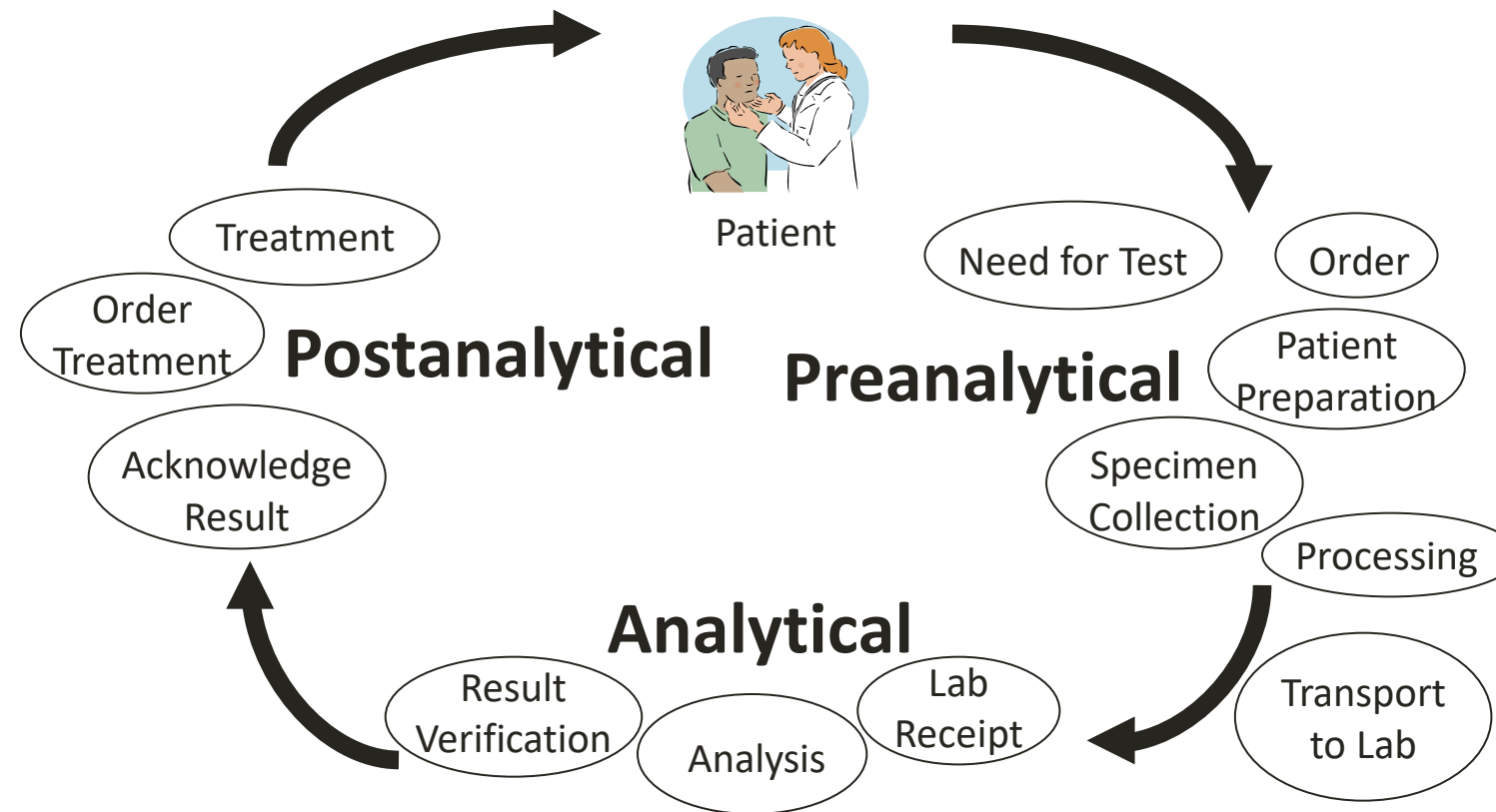
1. List current challenges in transporting samples from an offsite collection facility to the central, core clinical laboratory
2. Describe the need for standard instructions for external sample transport
3. Identify resources that could be implemented in mitigating errors in this portion of the preanalytical phase of the total testing process

Vanderbilt Medical Center



- 1019 beds (adult)
- 343 beds (children)
- Expansive outreach
- >6 million tests a year

Total Testing Process



Avoiding Titanic & Costly Errors

Šimundić AM. Avoiding Titanic Errors. The Pathologist. May 2015. Green S. Clin Biochem. 2013 Sep;46(13-14):1175-9.

Avoiding Titanic & Costly Errors

Analytical Phase 15%

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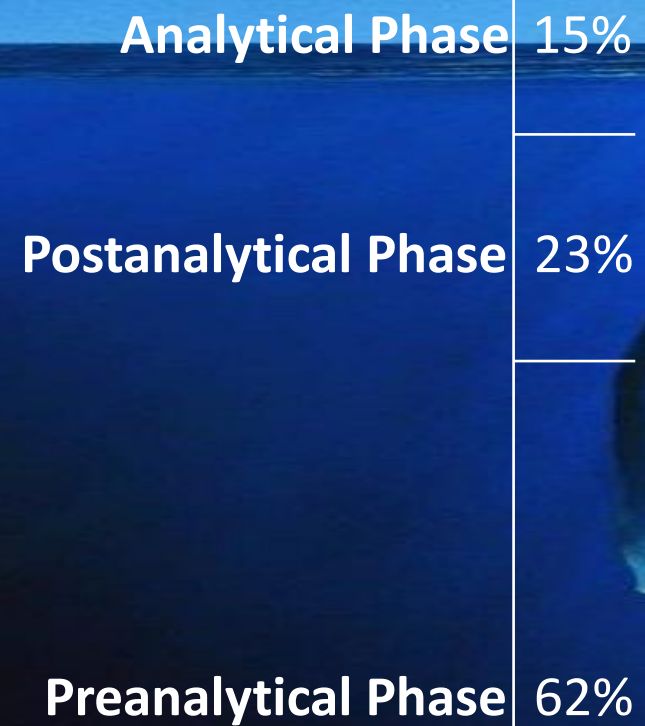
Avoiding Titanic & Costly Errors

Analytical Phase 15%

Postanalytical Phase 23%

Šimundić AM. Avoiding Titanic Errors. The Pathologist. May 2015. Green S. Clin Biochem. 2013 Sep;46(13-14):1175-9.

Avoiding Titanic & Costly Errors



Šimundić AM. Avoiding Titanic Errors. The Pathologist. May 2015. Green S. Clin Biochem. 2013 Sep;46(13-14):1175-9.

Avoiding Titanic & Costly Errors

- Preanalytical specimen error costs represent between 0.23% and 1.2% of total hospital operating costs.
- For a US hospital with approximately 650 beds, this cost is extrapolated to approximately \$1,199,122 per year.



Šimundić AM. Avoiding Titanic Errors. The Pathologist. May 2015. Green S. Clin Biochem. 2013 Sep;46(13-14):1175-9.

What comes to mind when you
hear external sample transport?
 ...

Extreme Heat and Cold

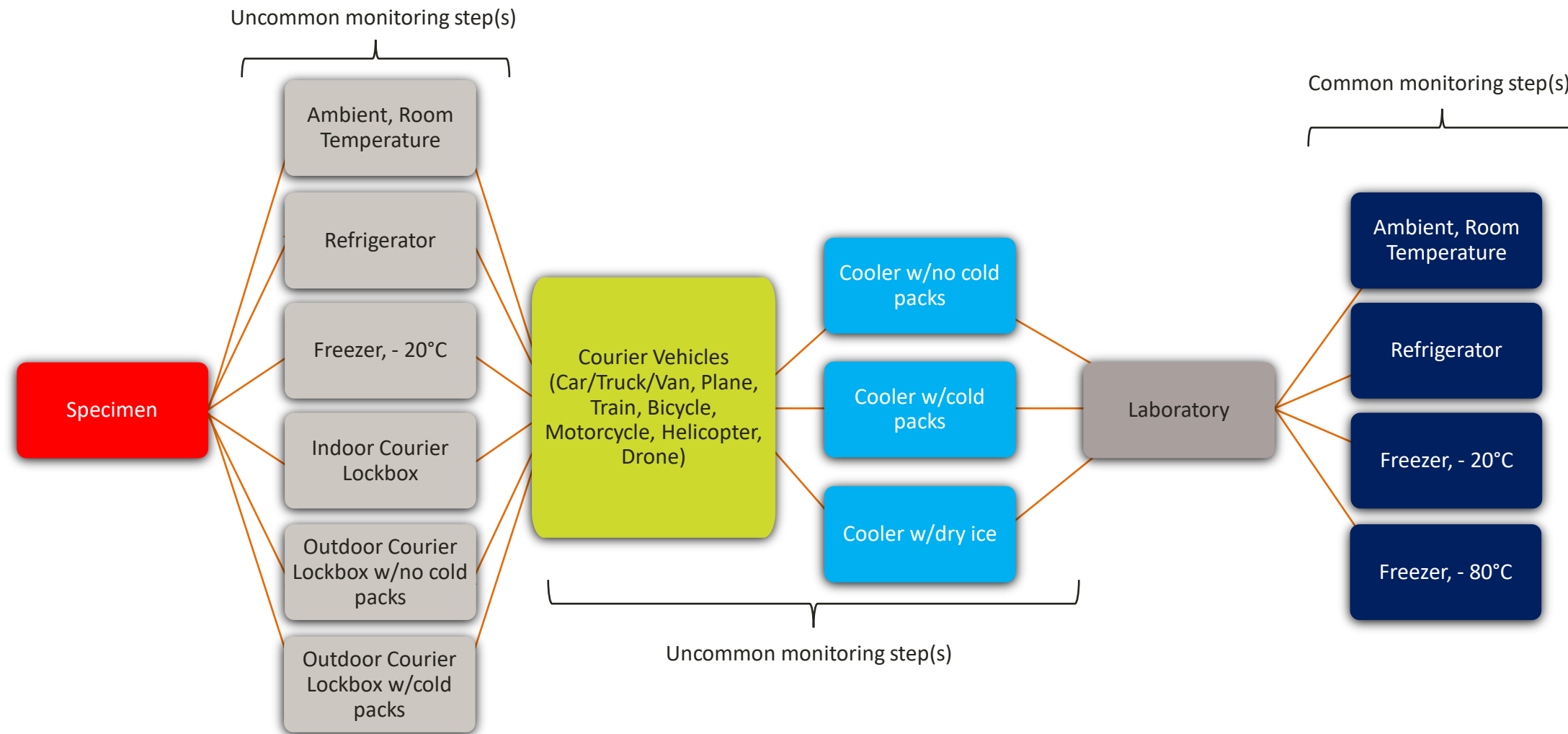
Extreme Heat and Cold



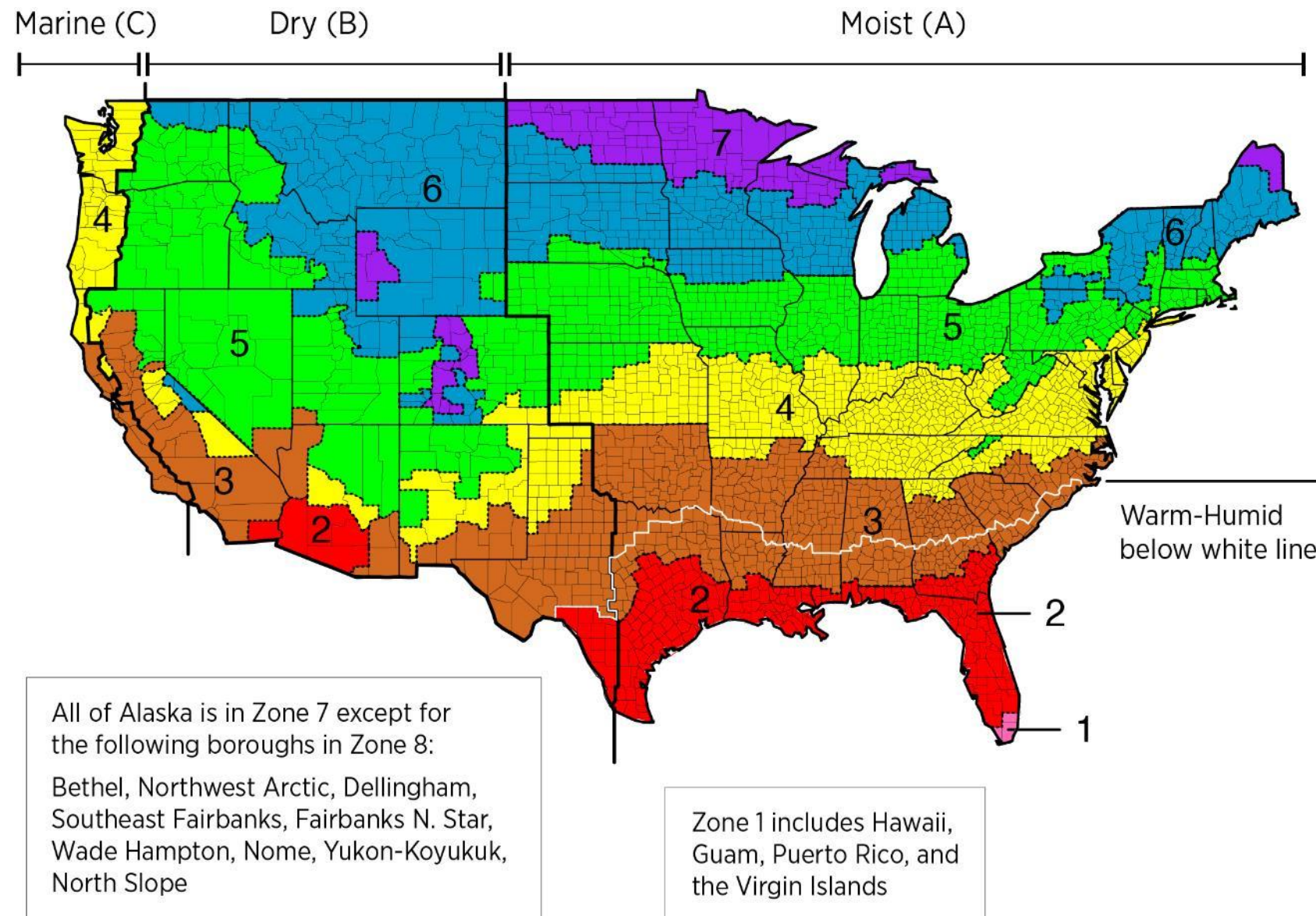
Extreme Heat and Cold



Transport and Storage Conditions

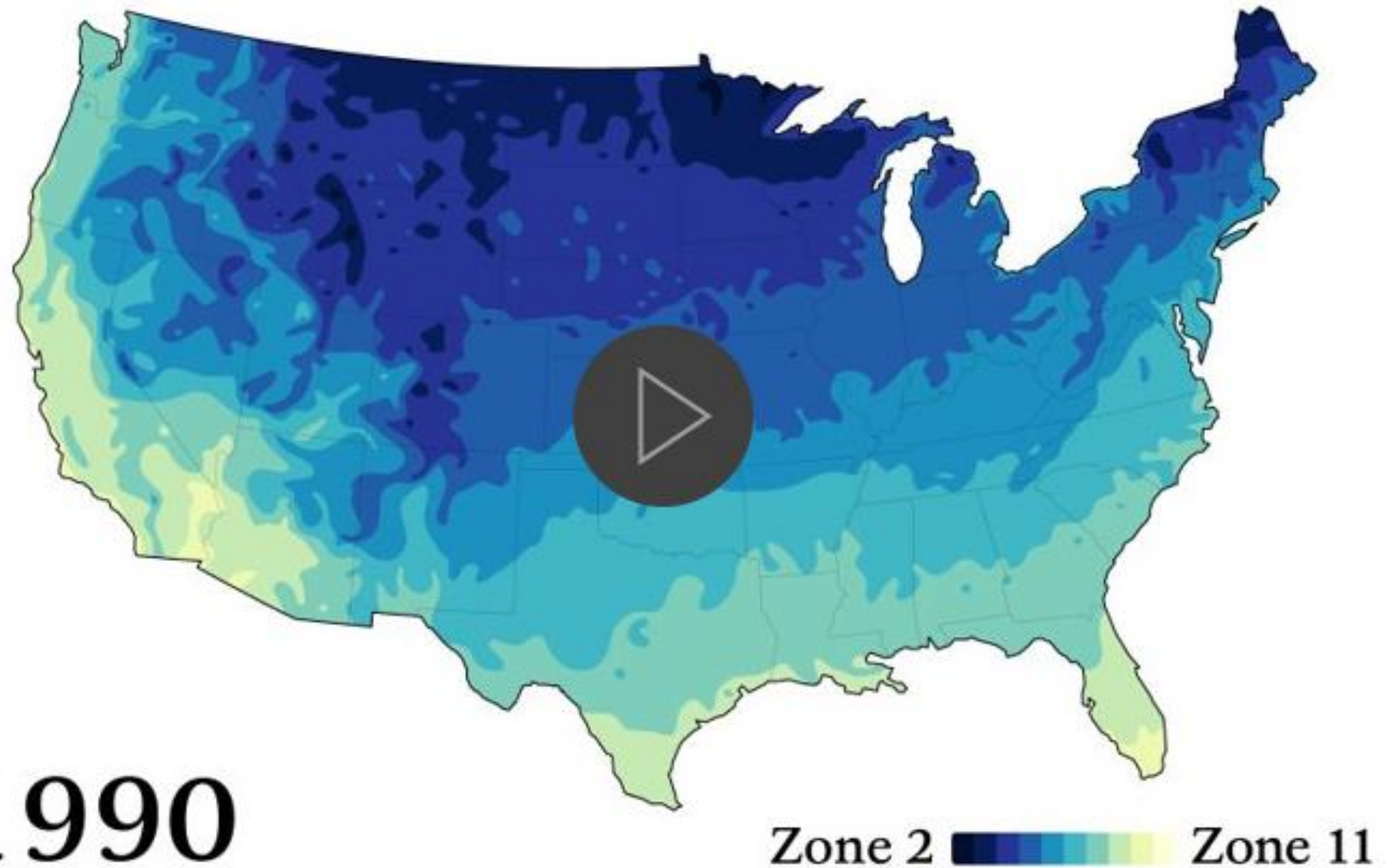


United States Climate Zones



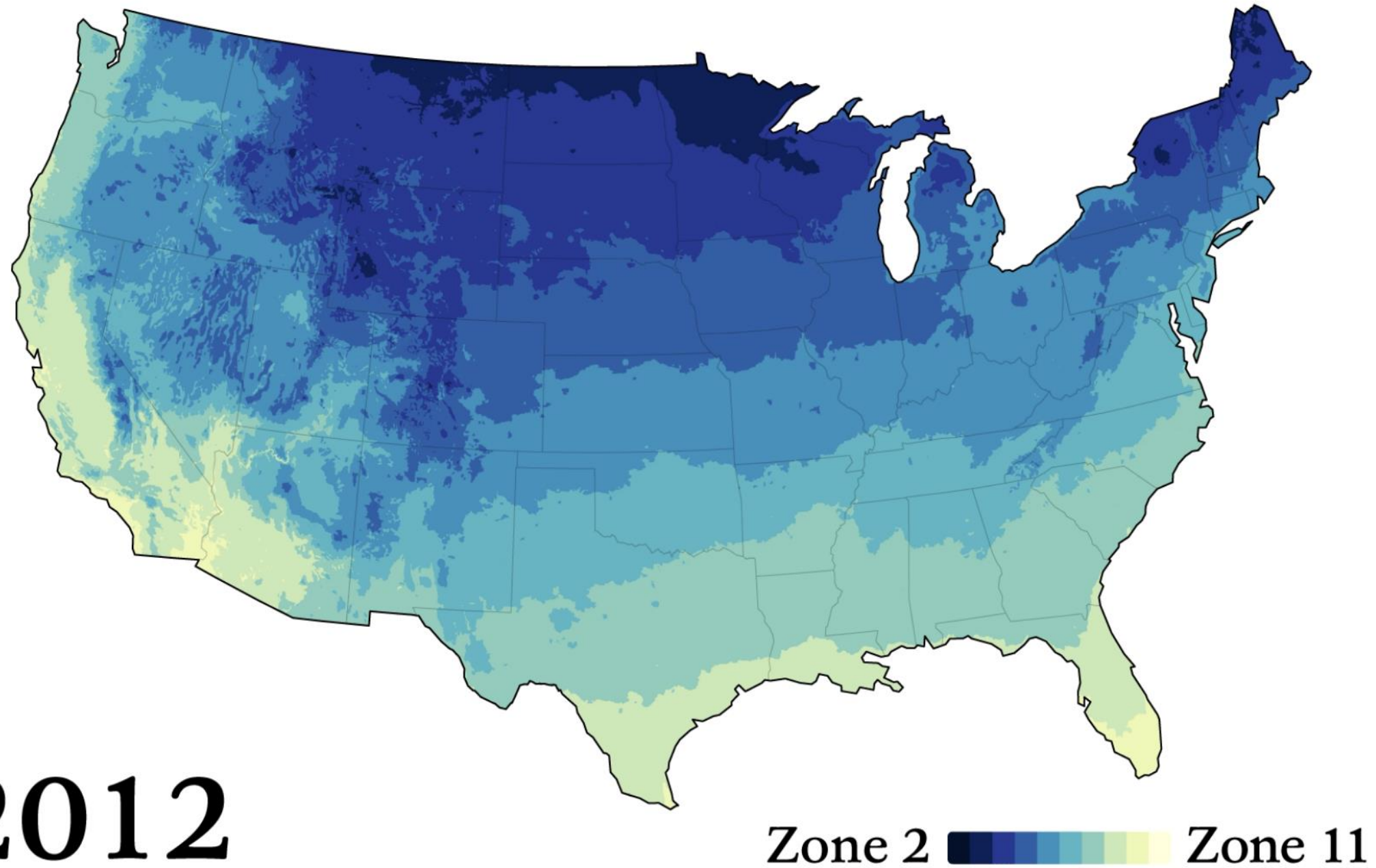
PLANT
HARDINESS
ZONES ARE
MOVING
NORTH IN THE
U.S. AT 13
MILES PER
DECADE

1990



PLANT
HARDINESS
ZONES ARE
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2012



Climate Challenges

- Temperature extremes



Climate Challenges



- Temperature extremes
- Longer periods of drought

Climate Challenges



- Temperature extremes
- Longer periods of drought
- Increase in number, duration, intensity of tropical storms

Climate Challenges

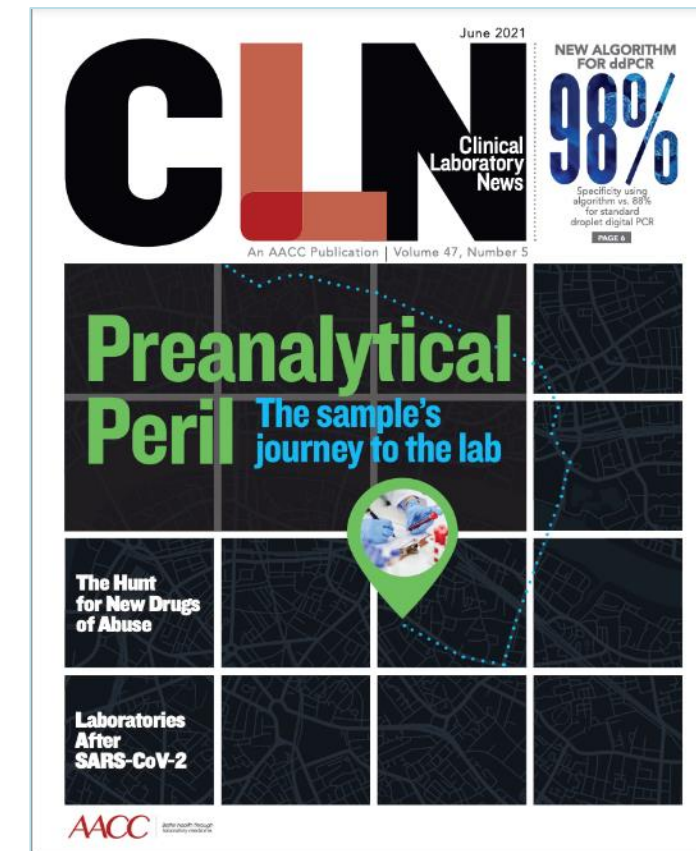


- Temperature extremes
- Longer periods of drought
- Increase in number, duration, intensity of tropical storms
- Changes in precipitation patterns

Samples Must be Delivered: Neither Heat, Nor Snow...

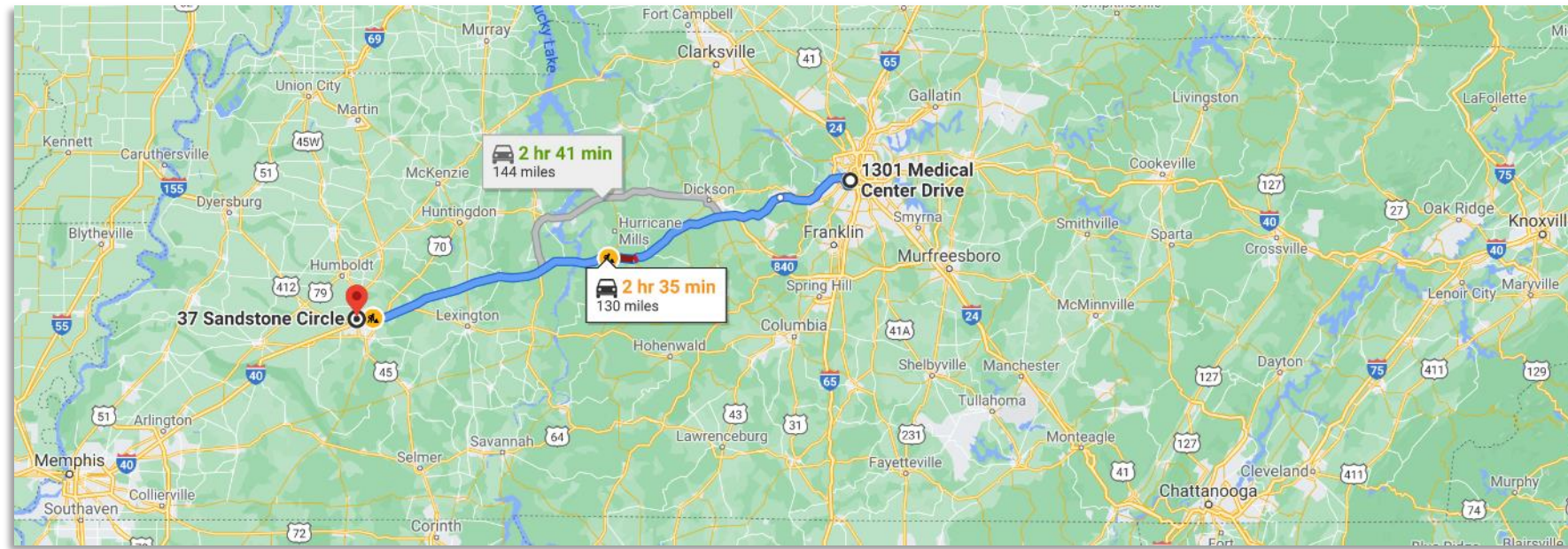
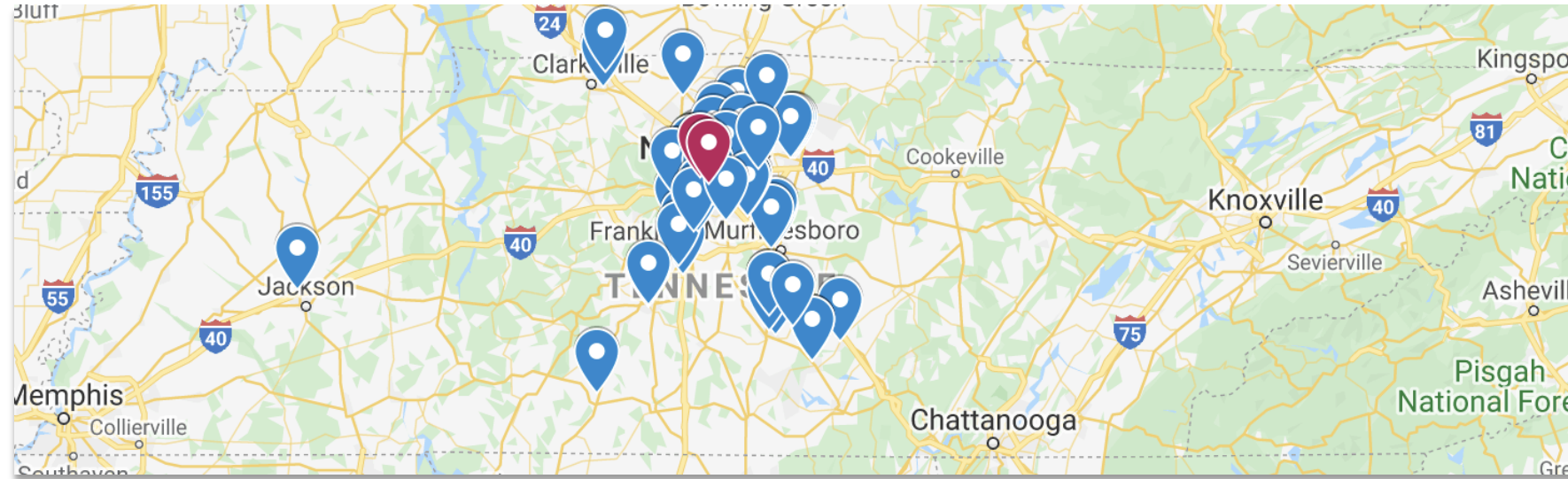


New York City Post Office on 8th Avenue, New York, New York



Case Vignette

Vanderbilt External Sample Collection Sites

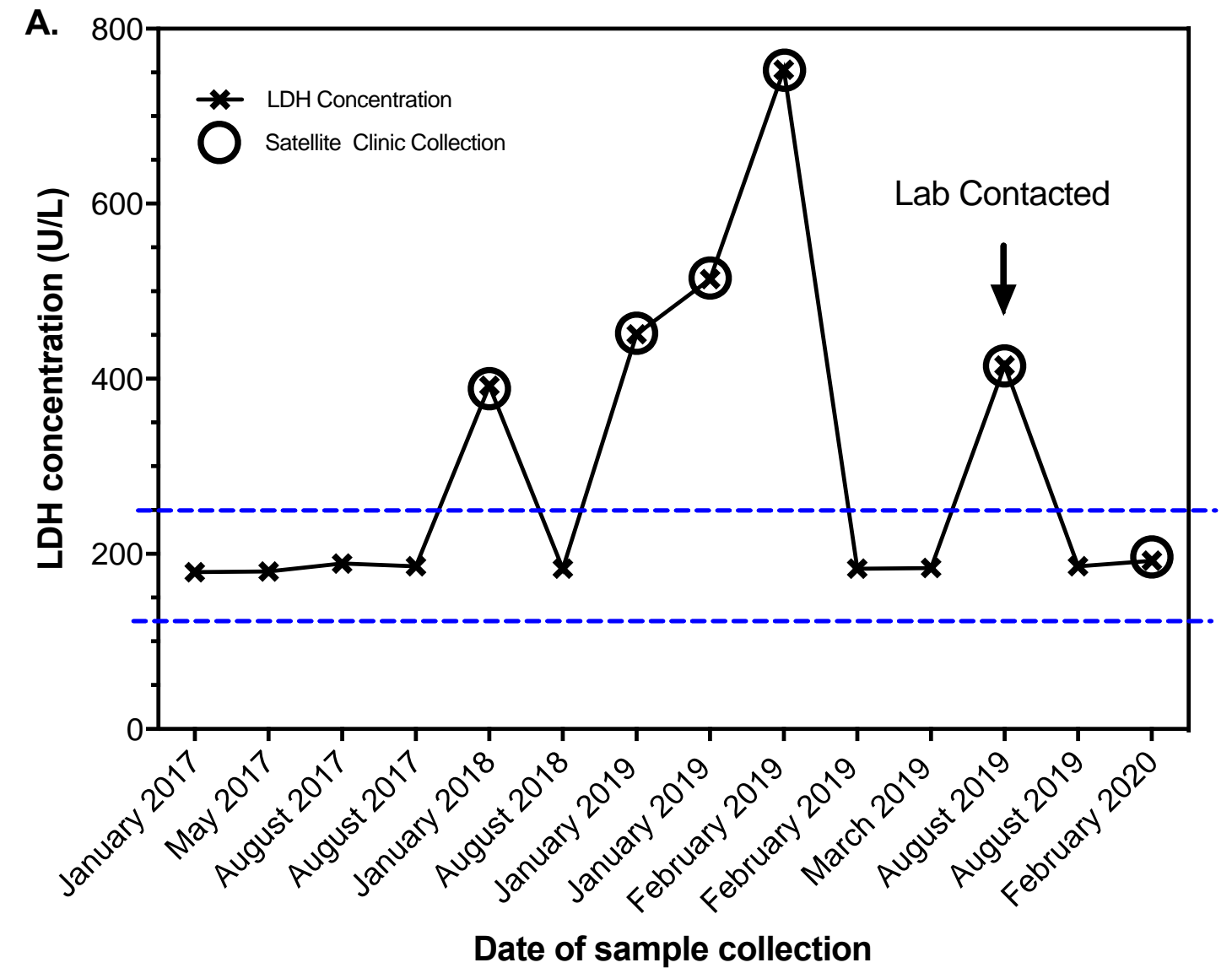


Case Vignette

- 68-year-old female
- History of giant cell tumor of the sacrum,
status post-resection

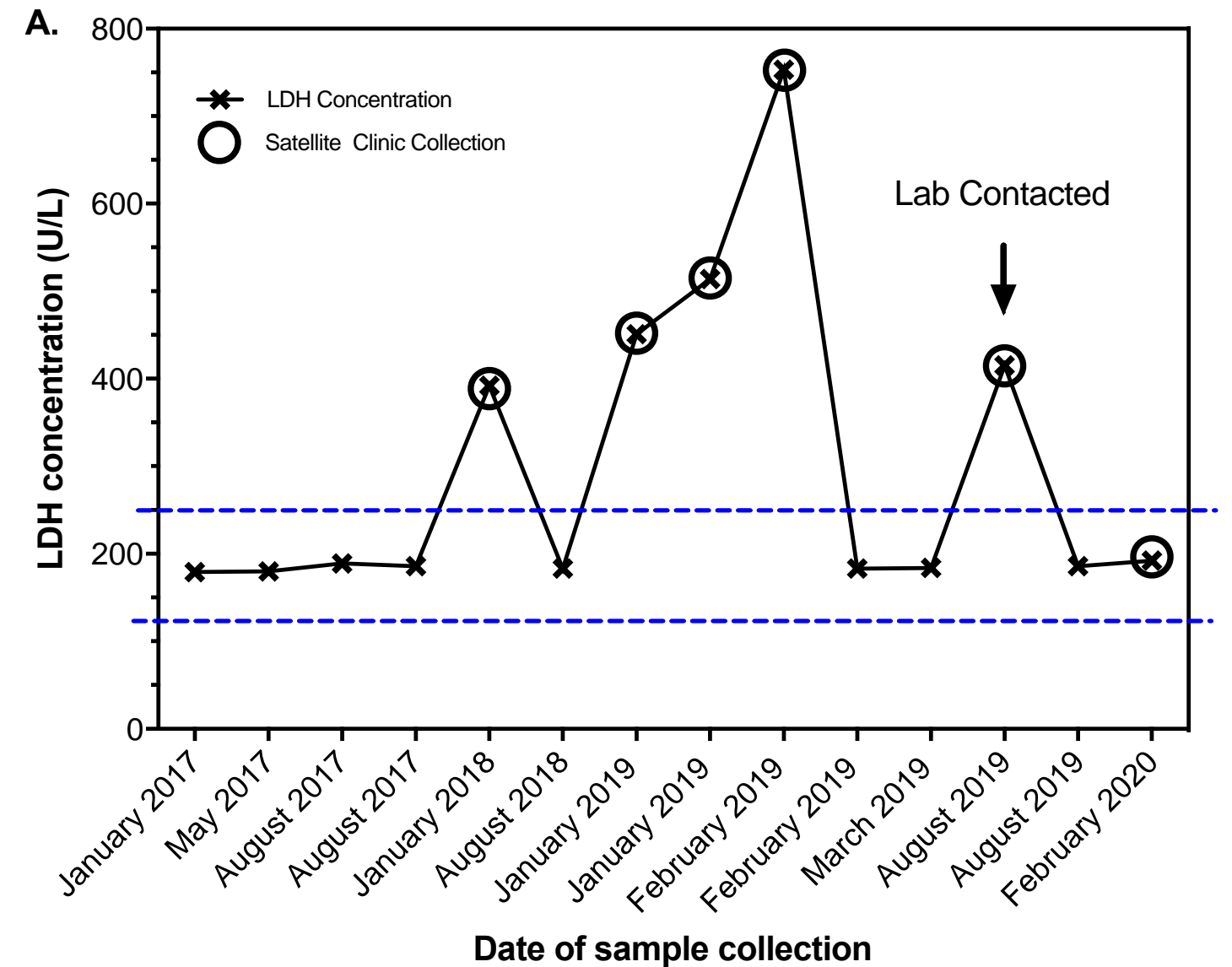
Case Vignette

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- Multiple elevated LDH measurements (3x) over 2m



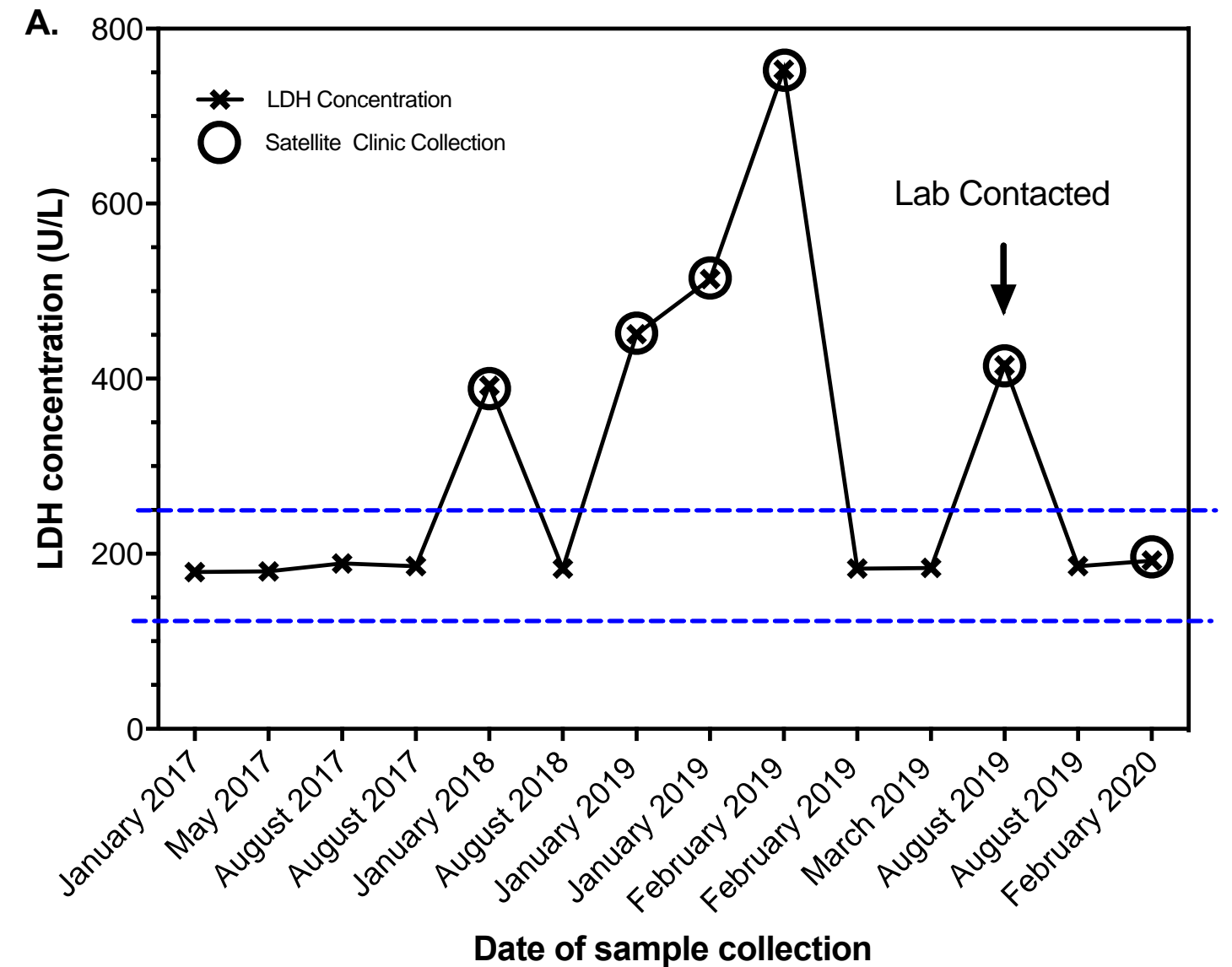
Case Vignette

- 68-year-old female
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- Multiple elevated LDH measurements (3x) over 2m
- Proposed additional work up to include LDH isoenzyme, PET and CT scans

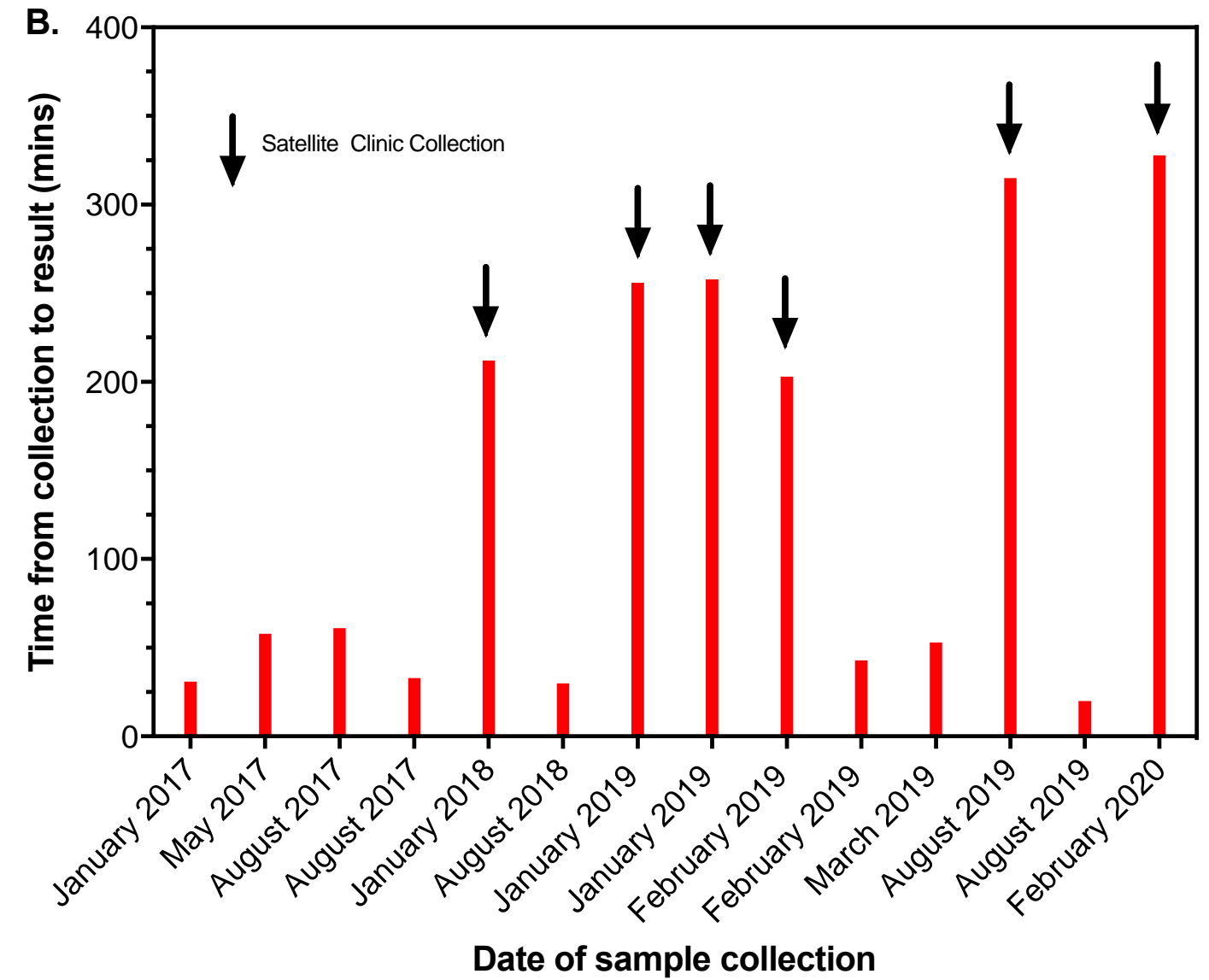
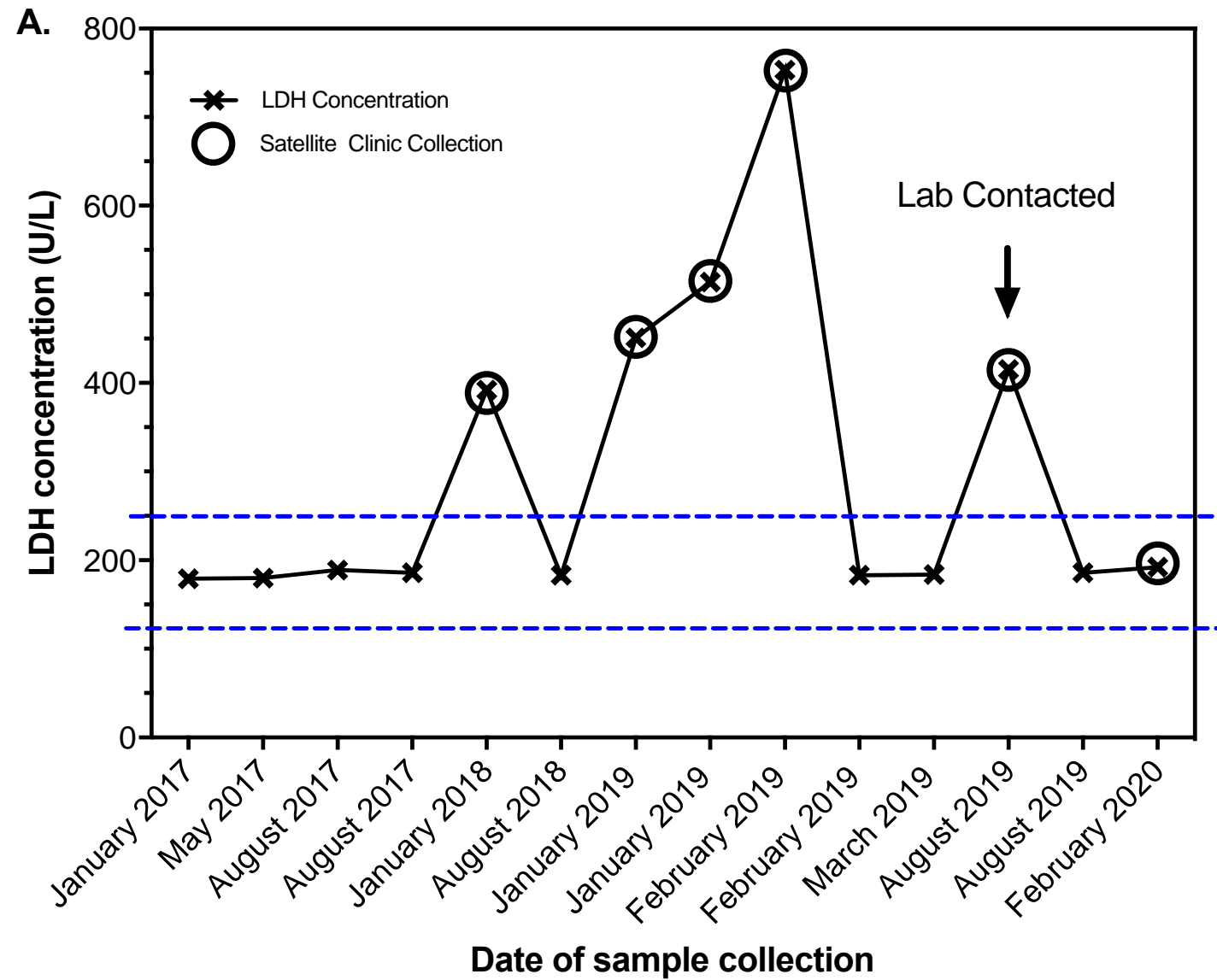


Case Vignette

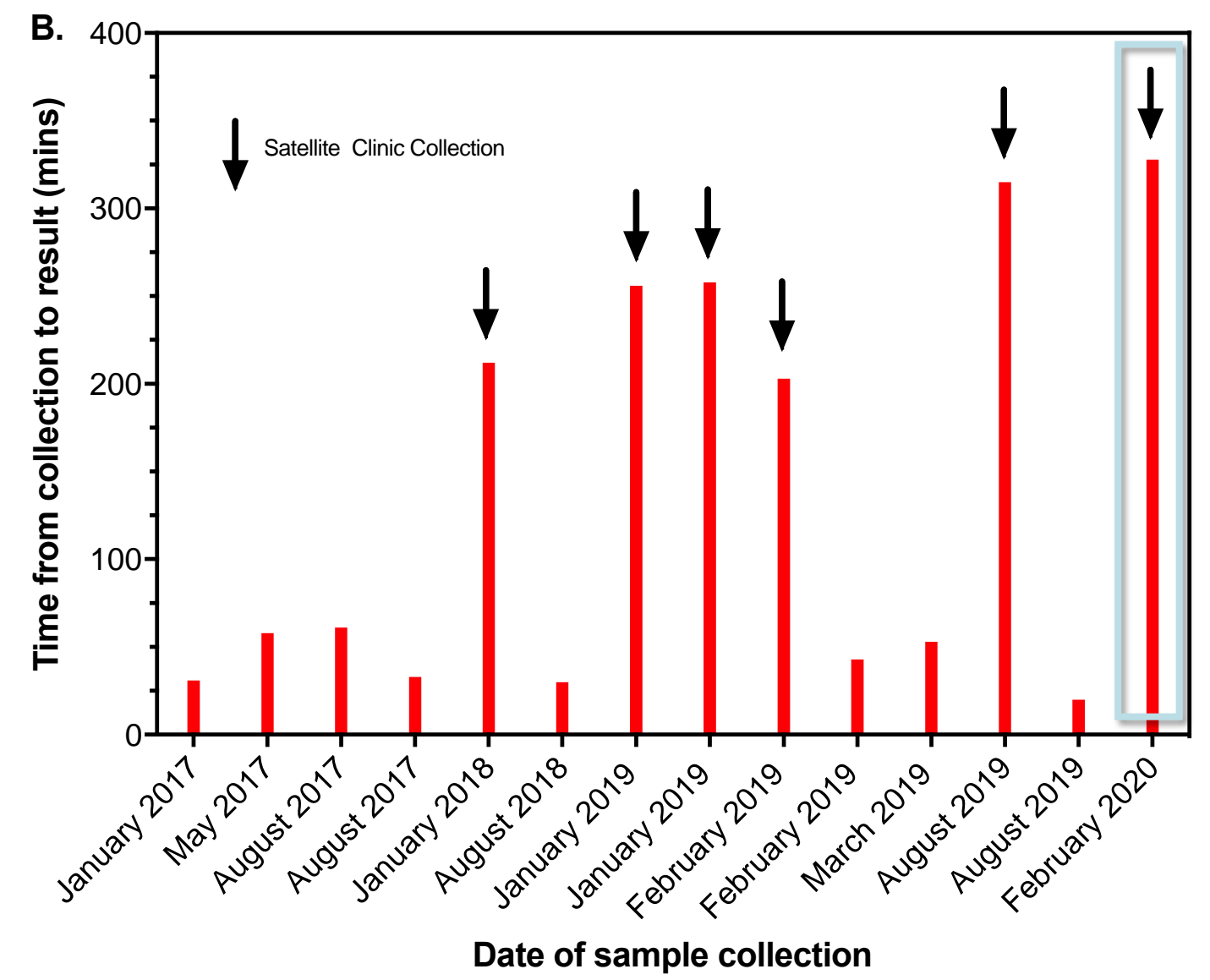
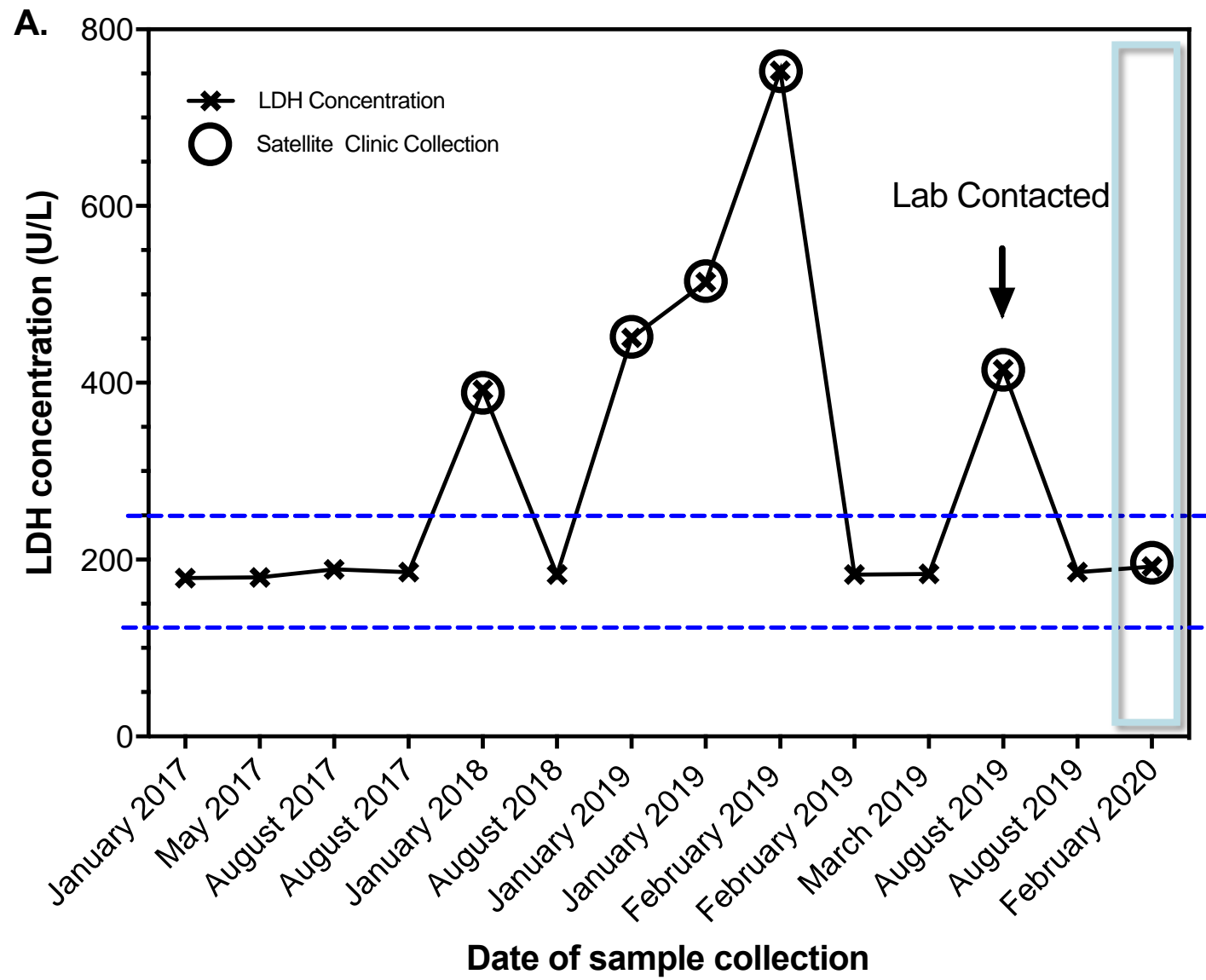
- 68-year-old female
- History of giant cell tumor of the sacrum, status post-resection
- Multiple elevated LDH measurements (3x) over 2m
- Proposed additional work up to include LDH isoenzyme, PET and CT scans
- Is her tumor back?



Case Vignette

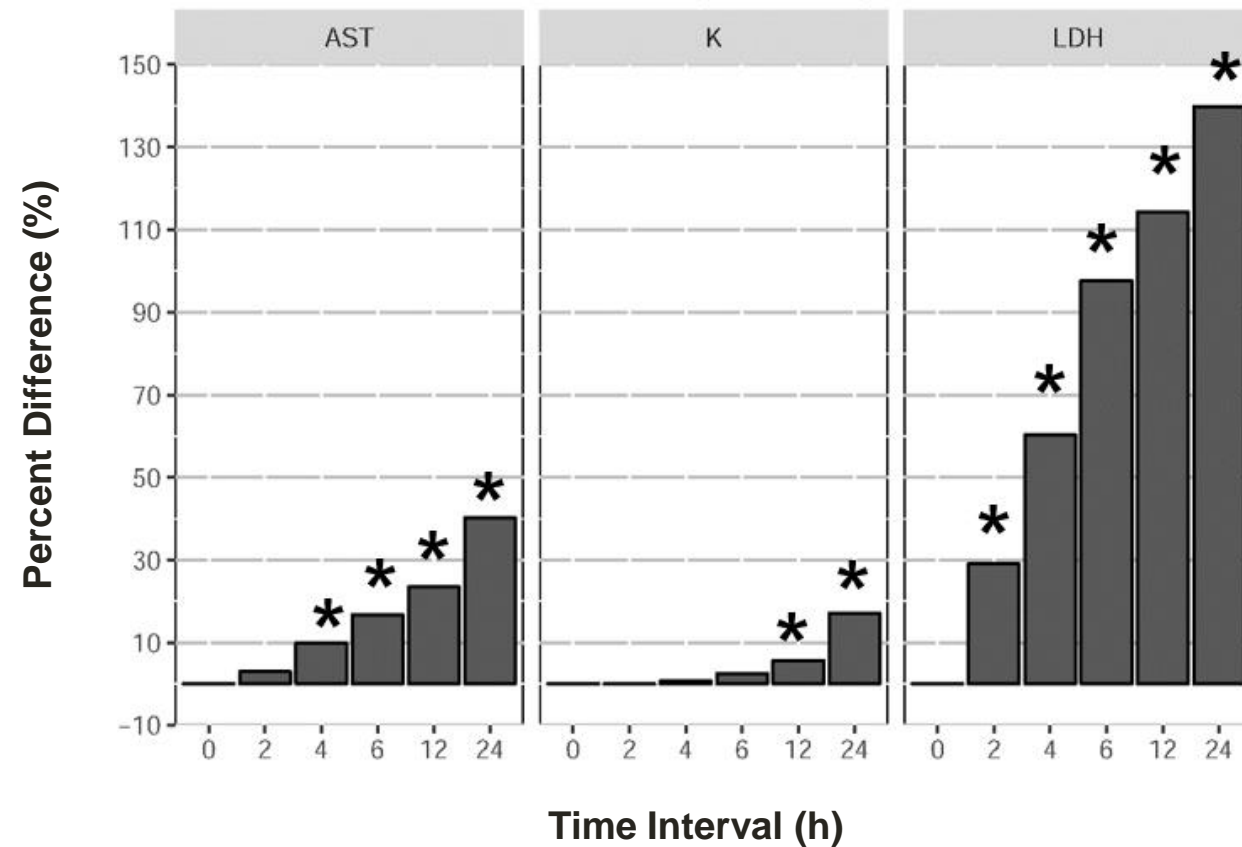


Case Vignette



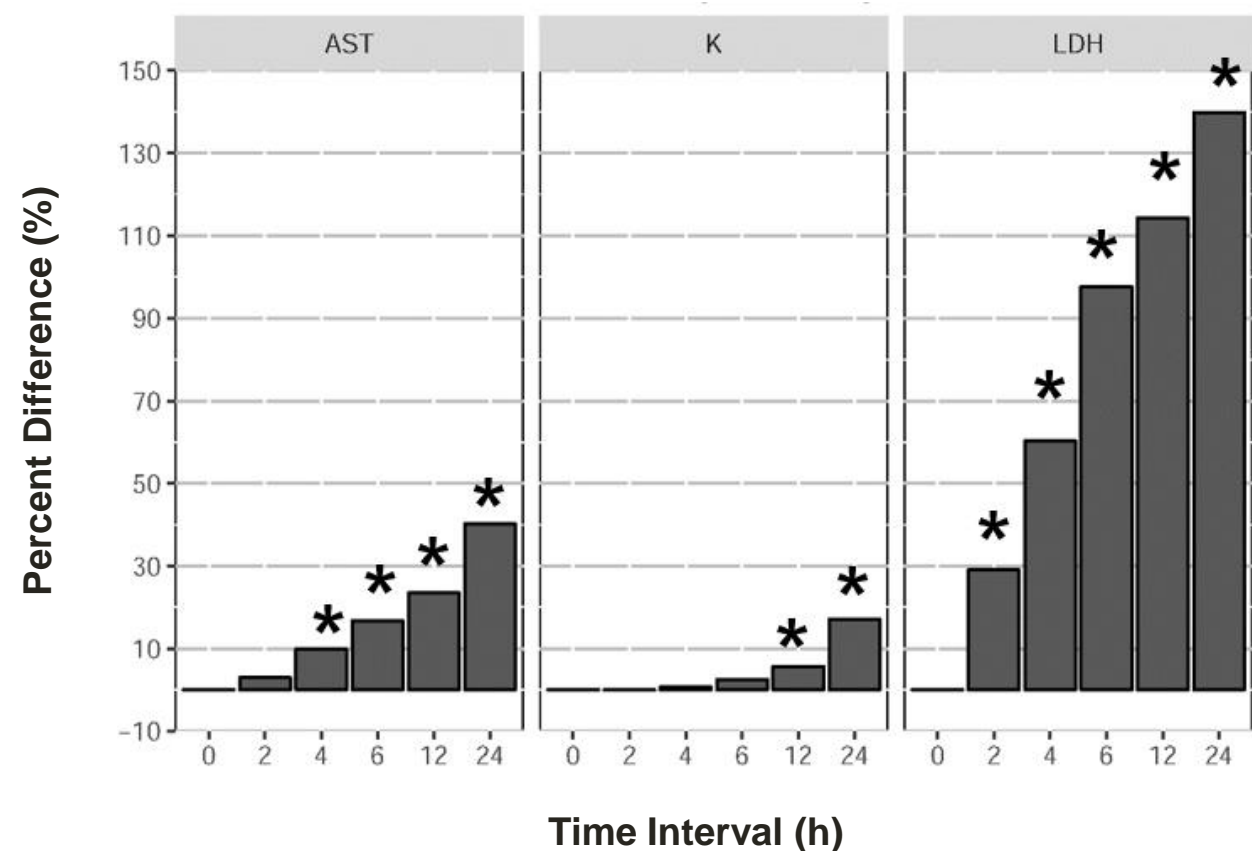
AST, K, LDH Increase in Refrigerated Li-Heparin Samples

A. PST at 1290g Centrifugation

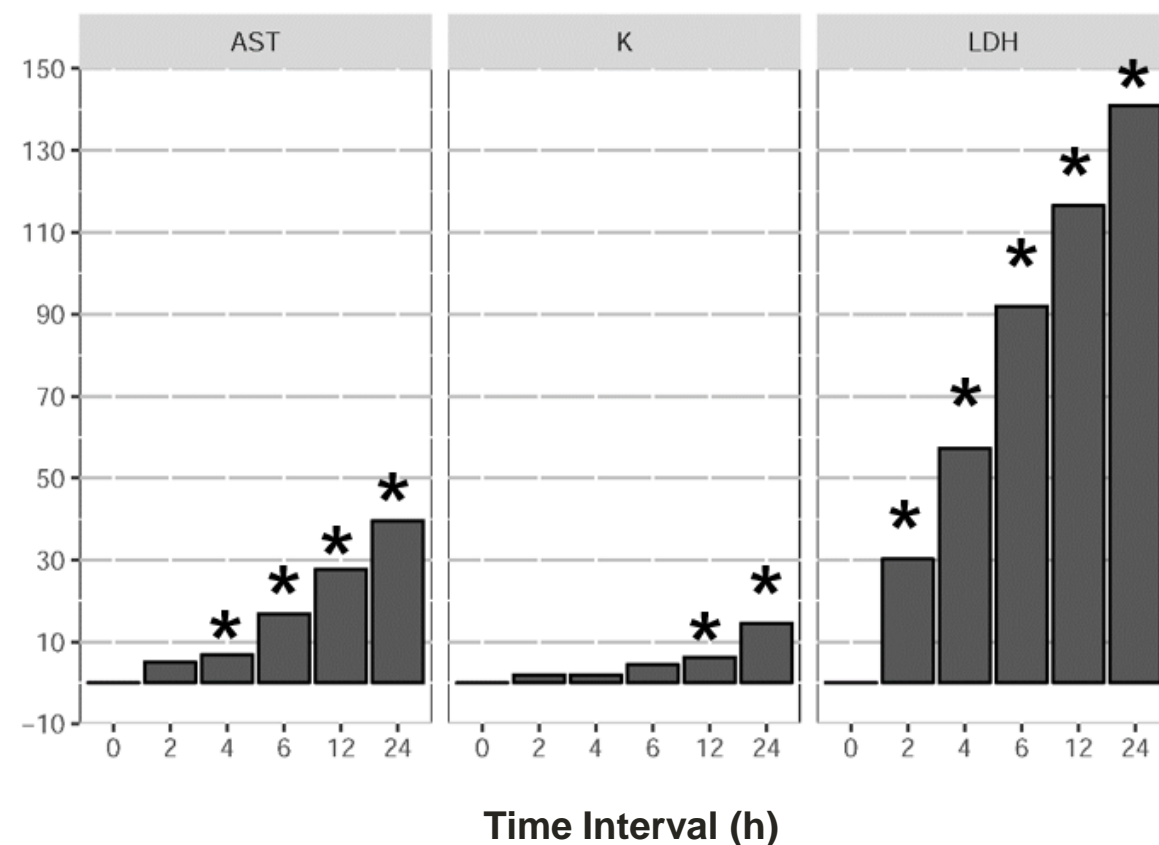


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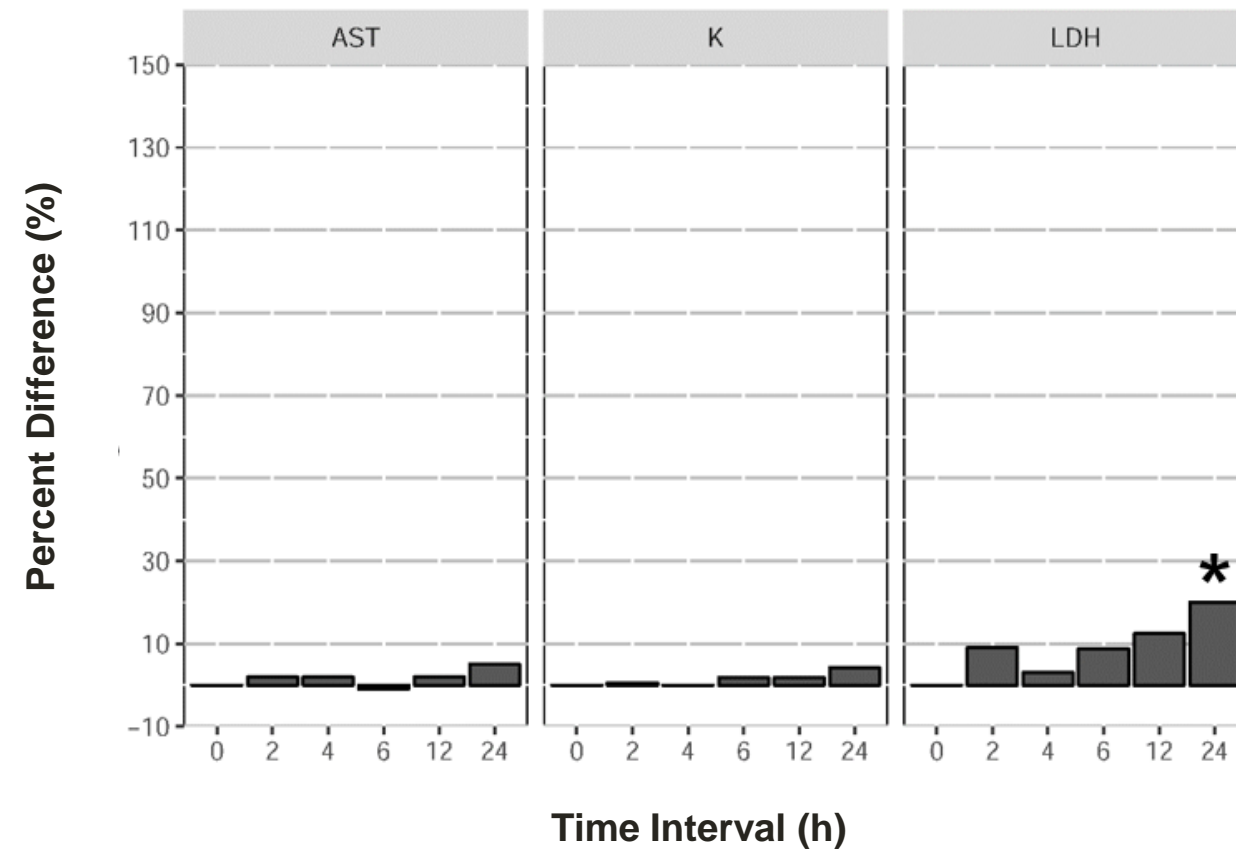
B. PST at 3010g Centrifugation



*SCL: Significant Change Limits (p<0.05)

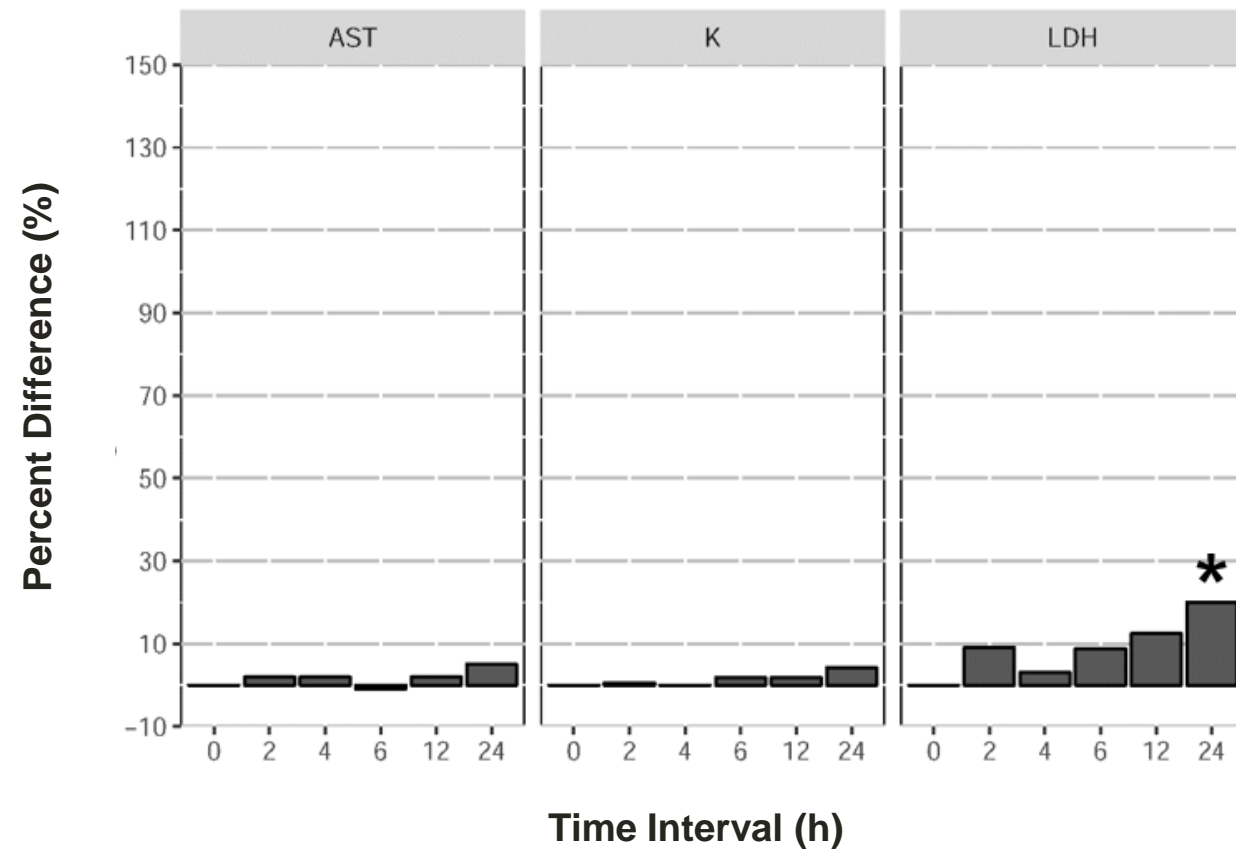
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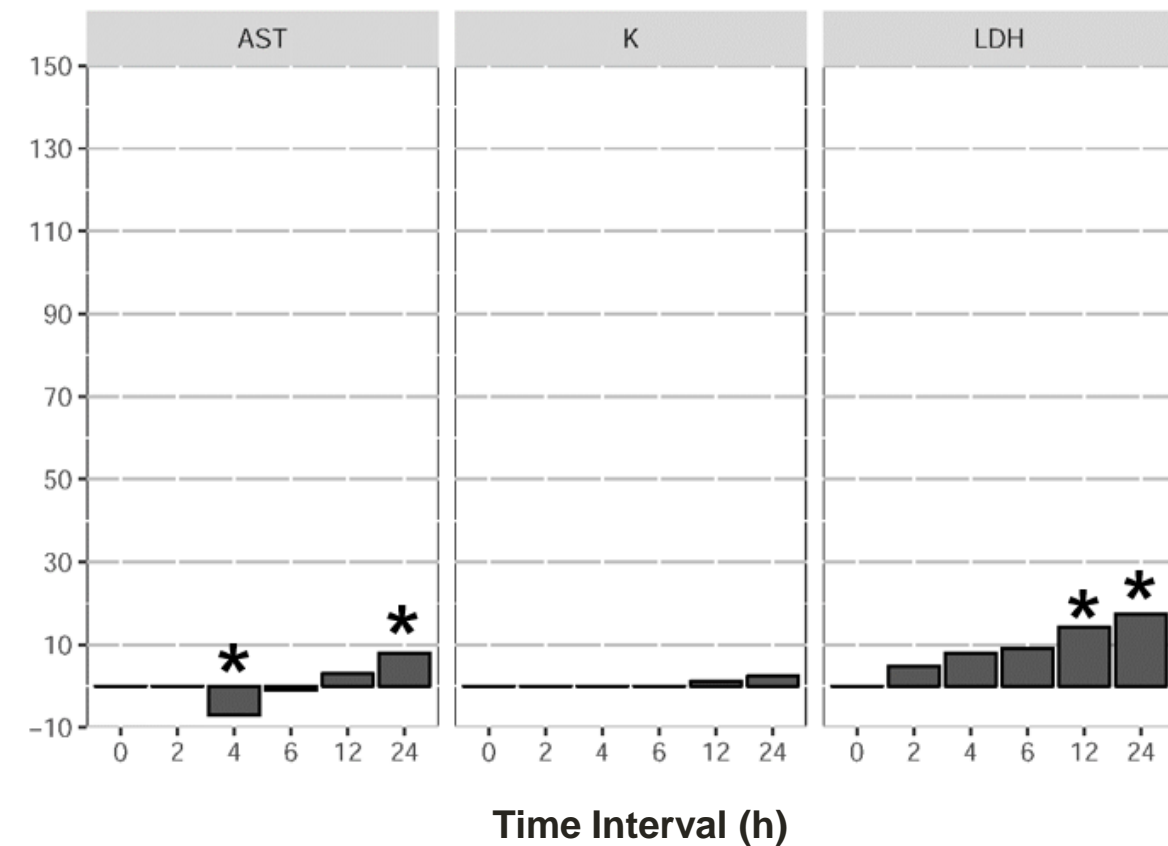


AST, K, LDH Increase in Refrigerated Li-Heparin Samples

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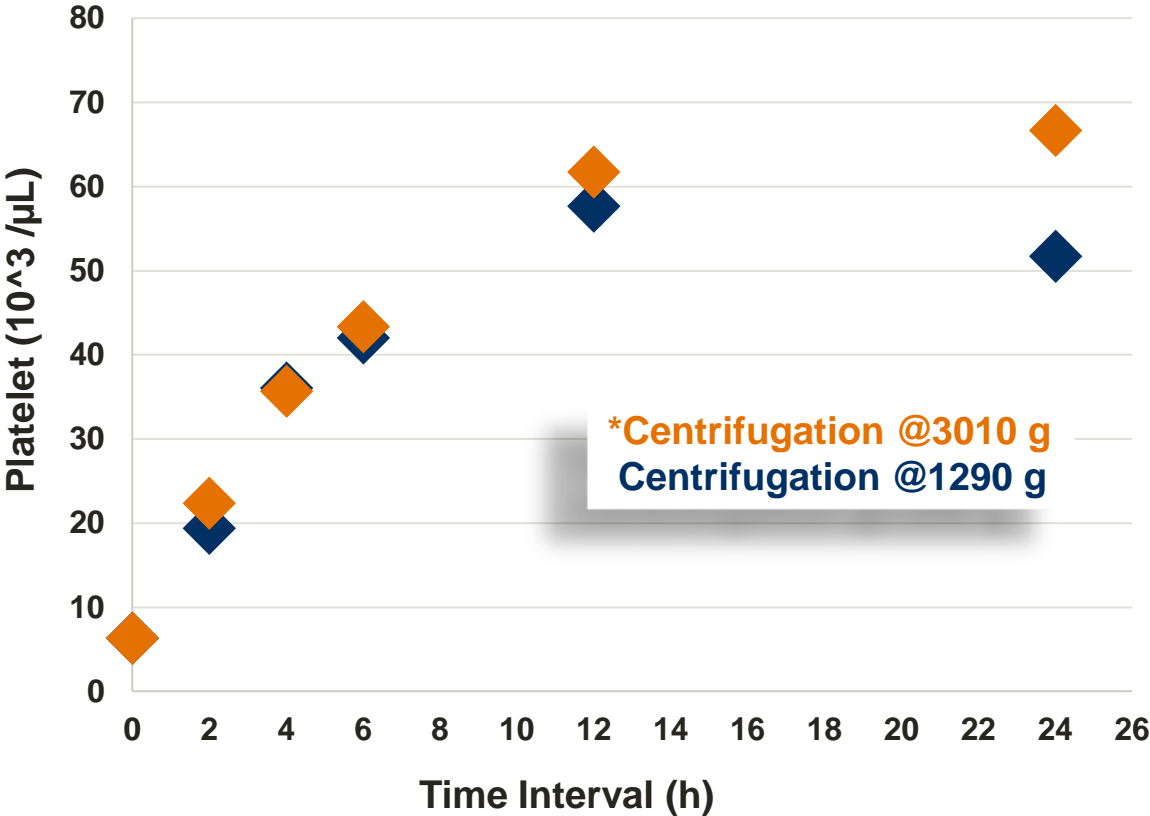
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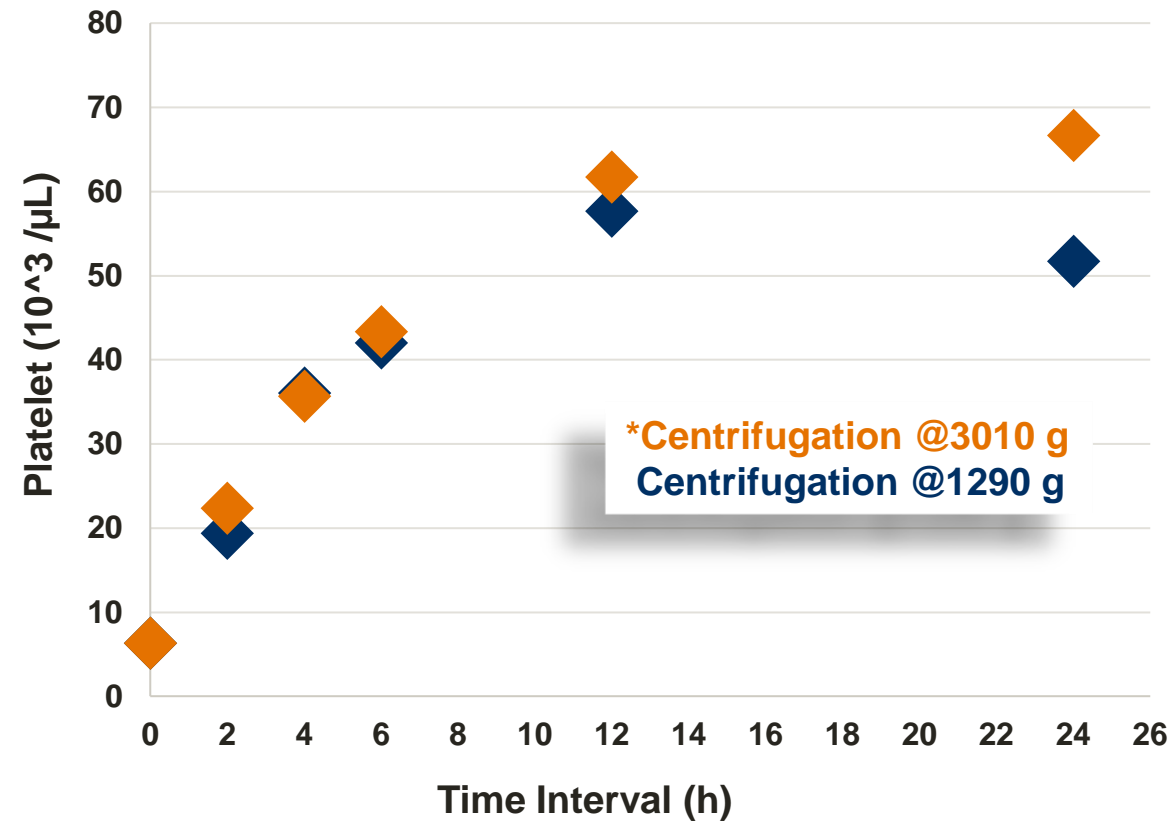
Residual Platelets

A. Platelet Count in Plasma Separator Tube (PST)

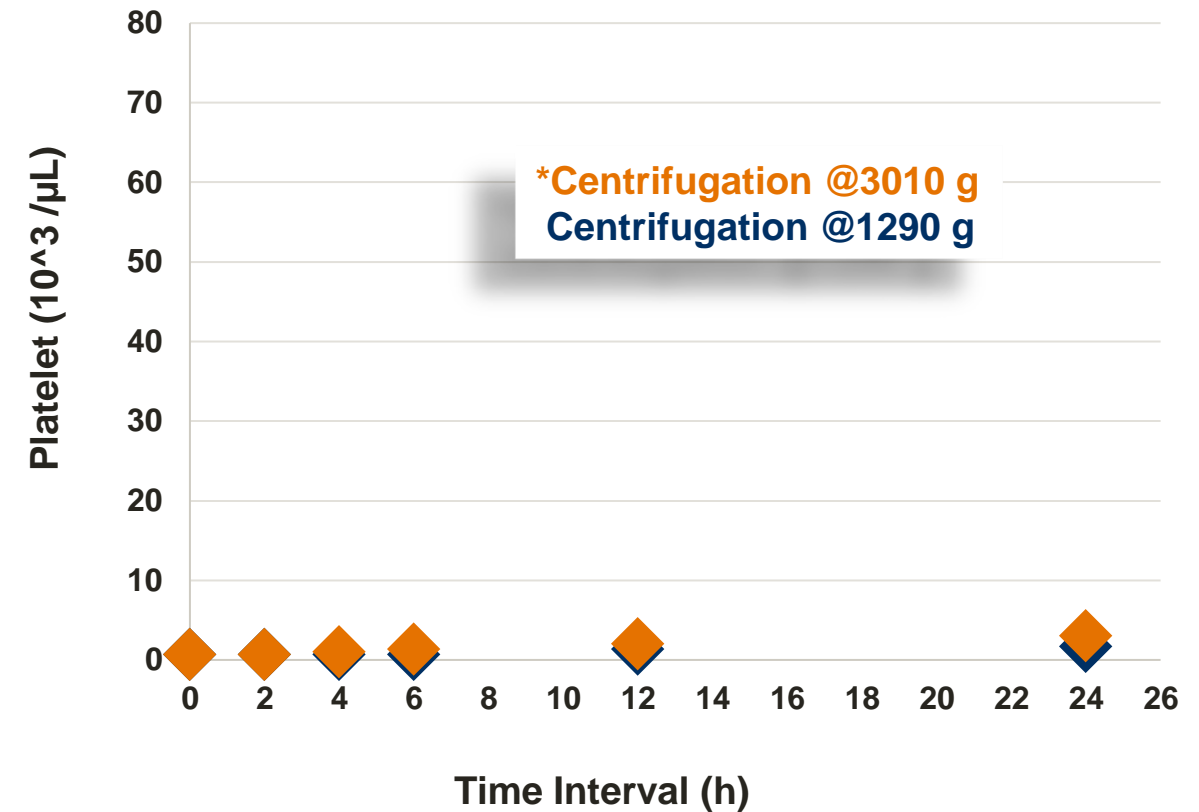


Residual Platelets

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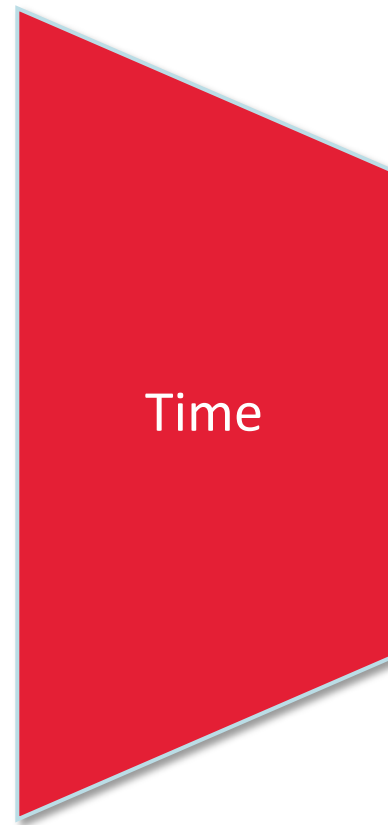
B. Platelet Count in Serum Separator Tube (SST)



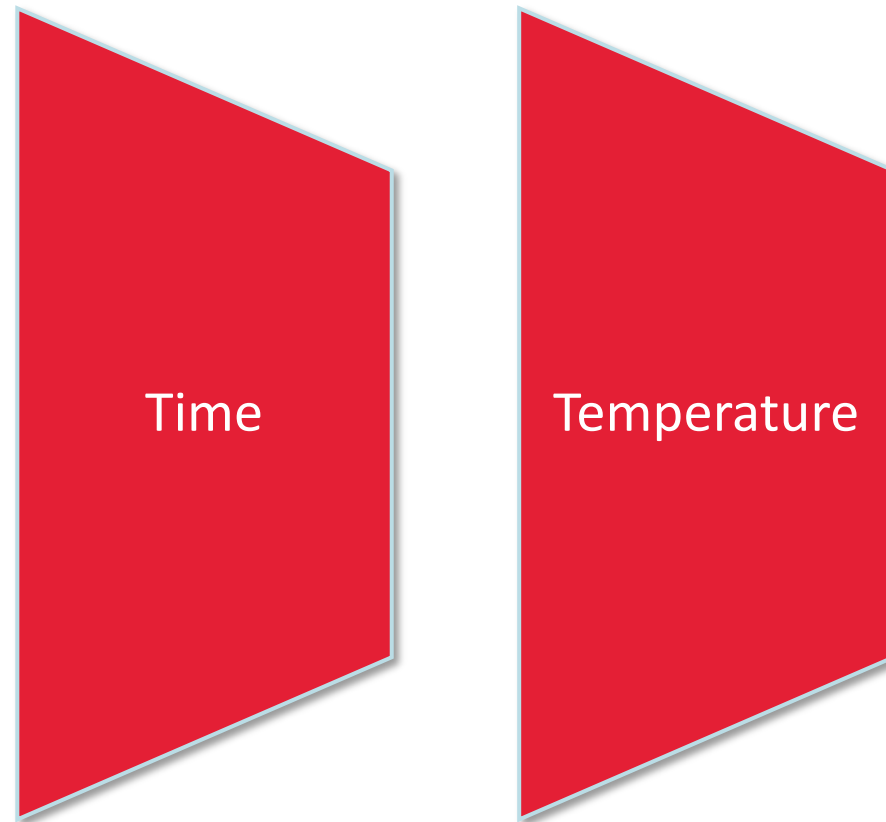
*Recommended centrifuge force to reduce platelets

Transport Challenges and Current State

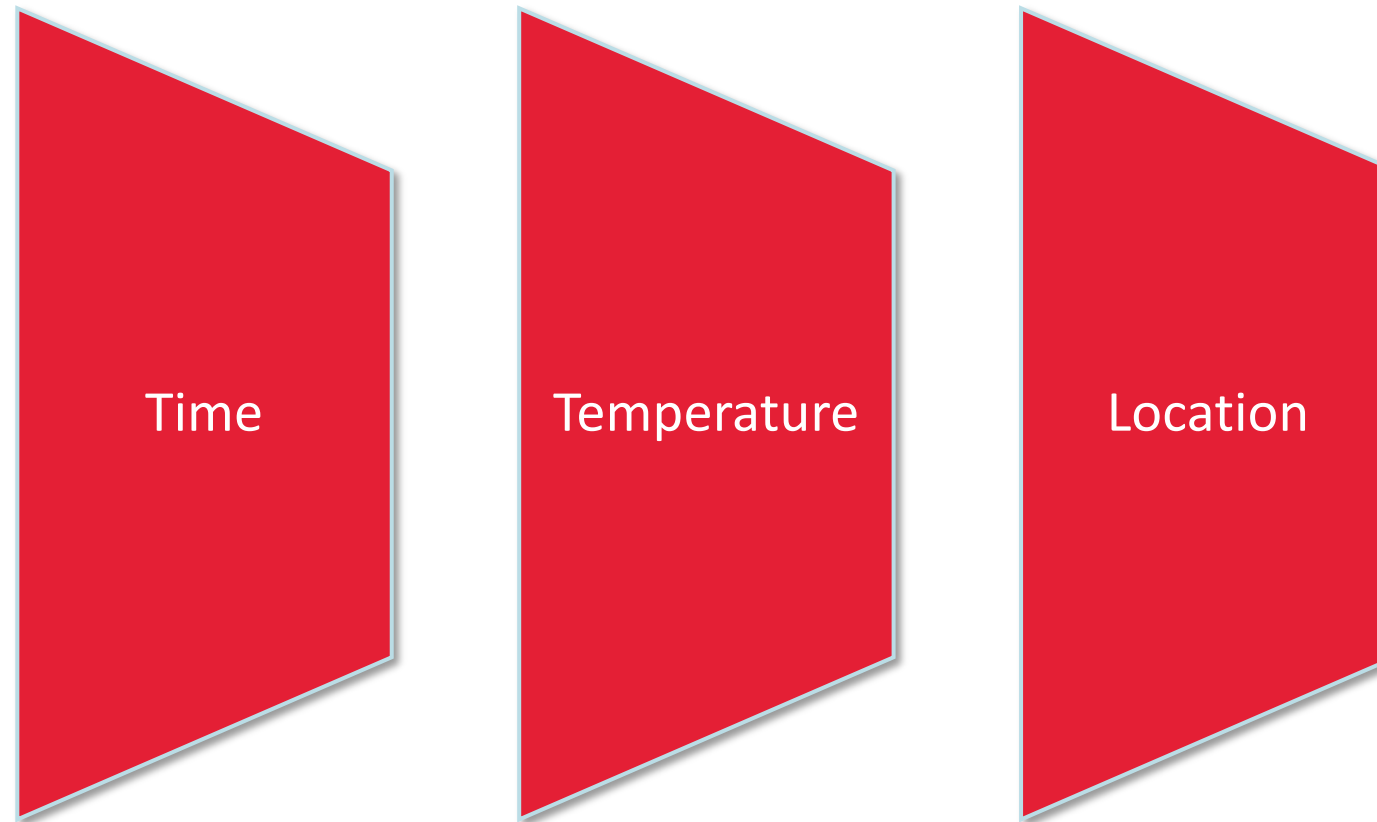
Monitoring Conditions for External Sample Transport



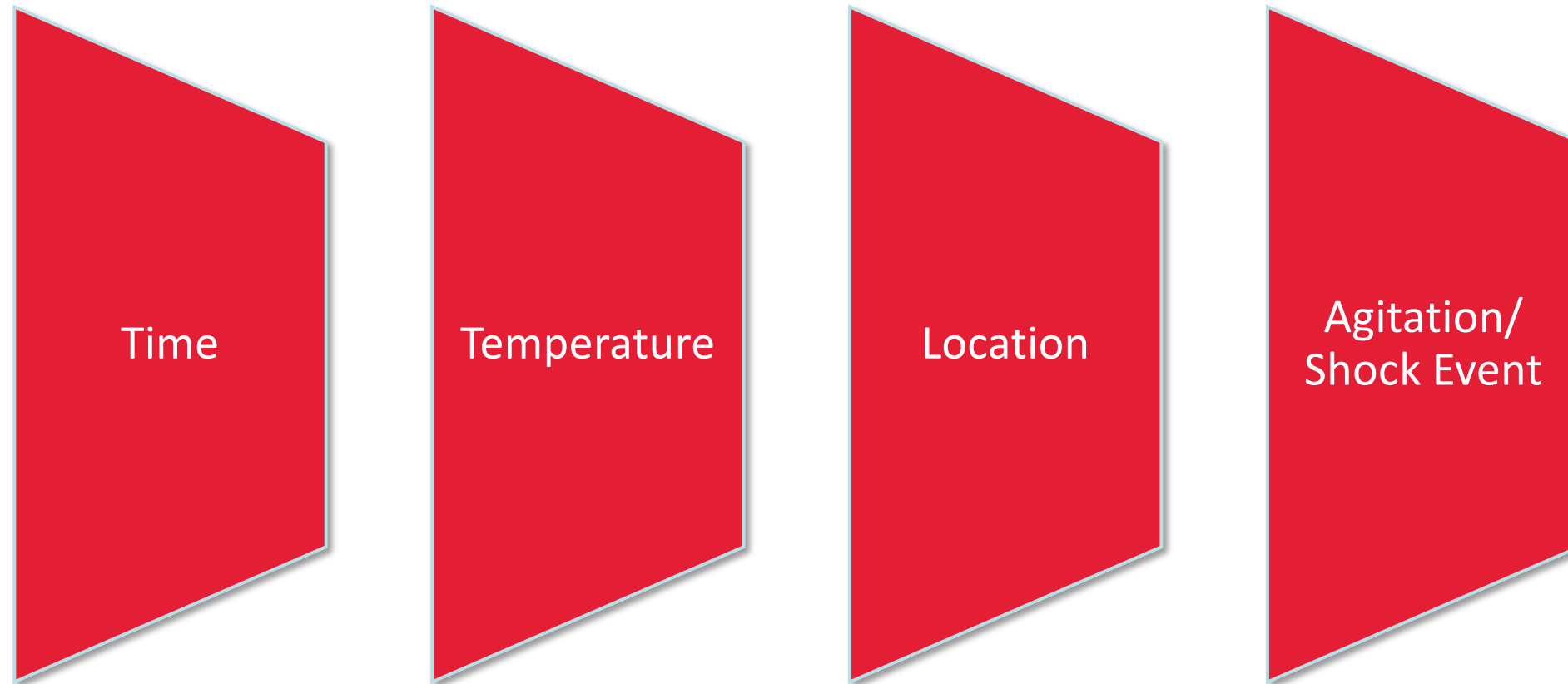
Monitoring Conditions for External Sample Transport



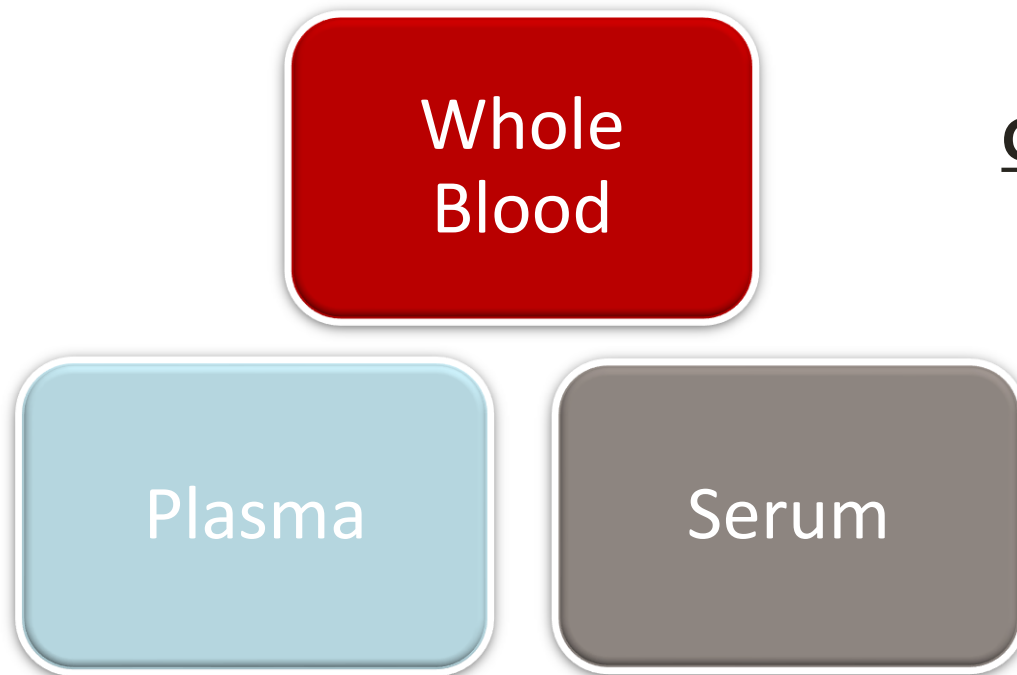
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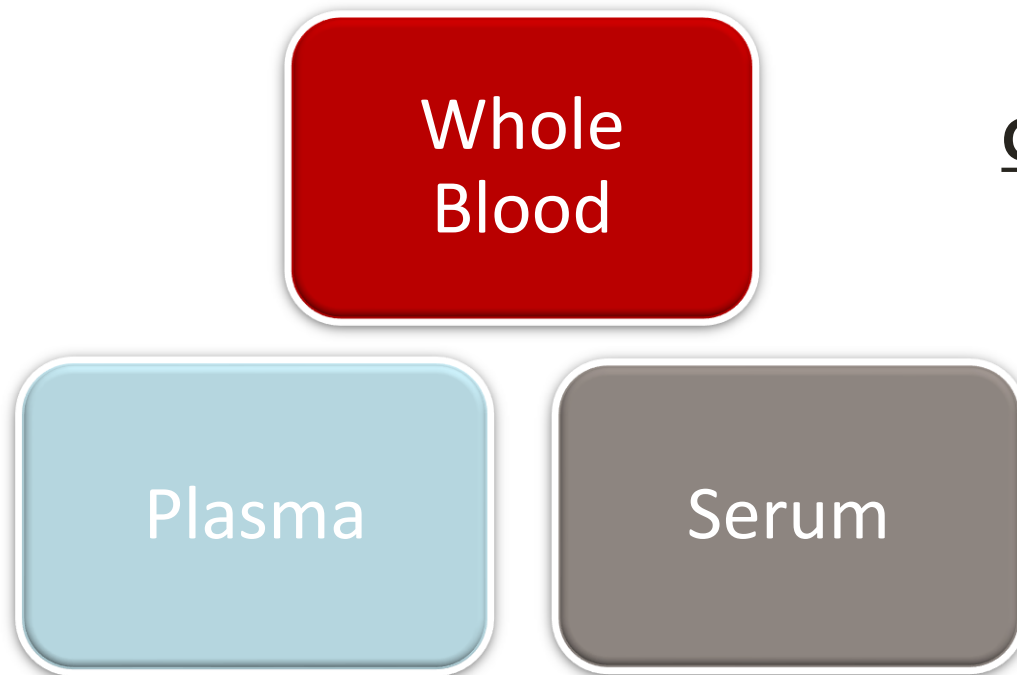


CLSI GP44-A4: Recommendations



General handling and processing recommendations

CLSI GP44-A4: Recommendations



General handling and processing recommendations

Stability is matrix/analyte dependent

Centrifuge and separate <2h

Keep specimen vertical

Store plasma/serum 2-8°C

Transport temps not to exceed 22°C

Courier Lockboxes

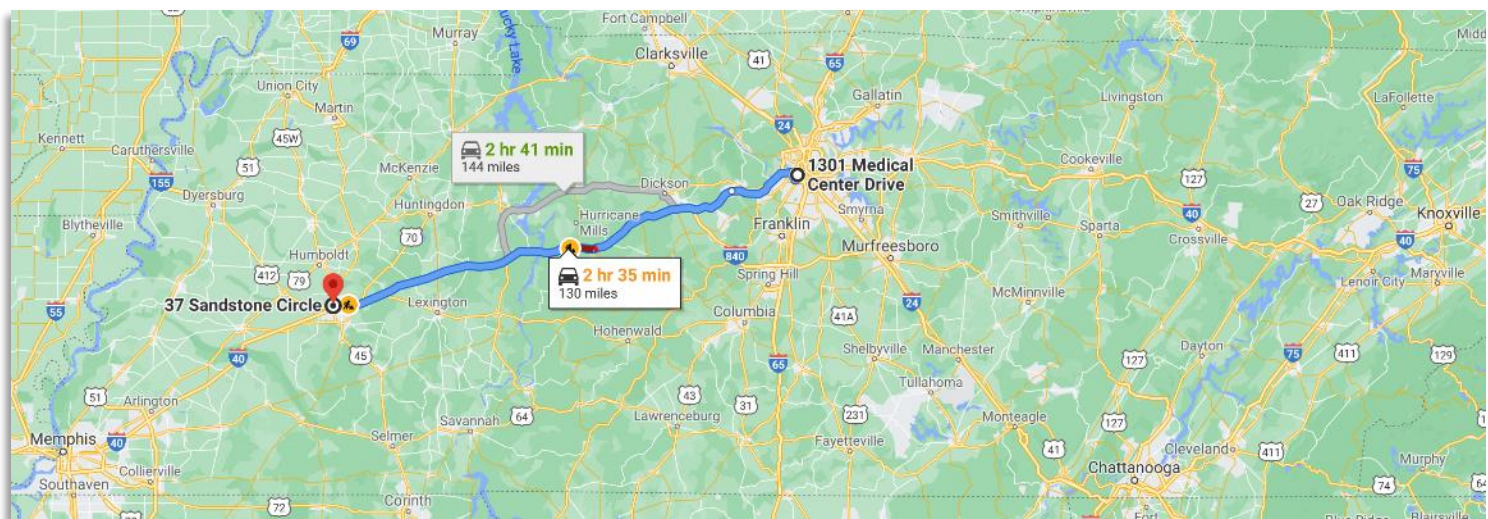
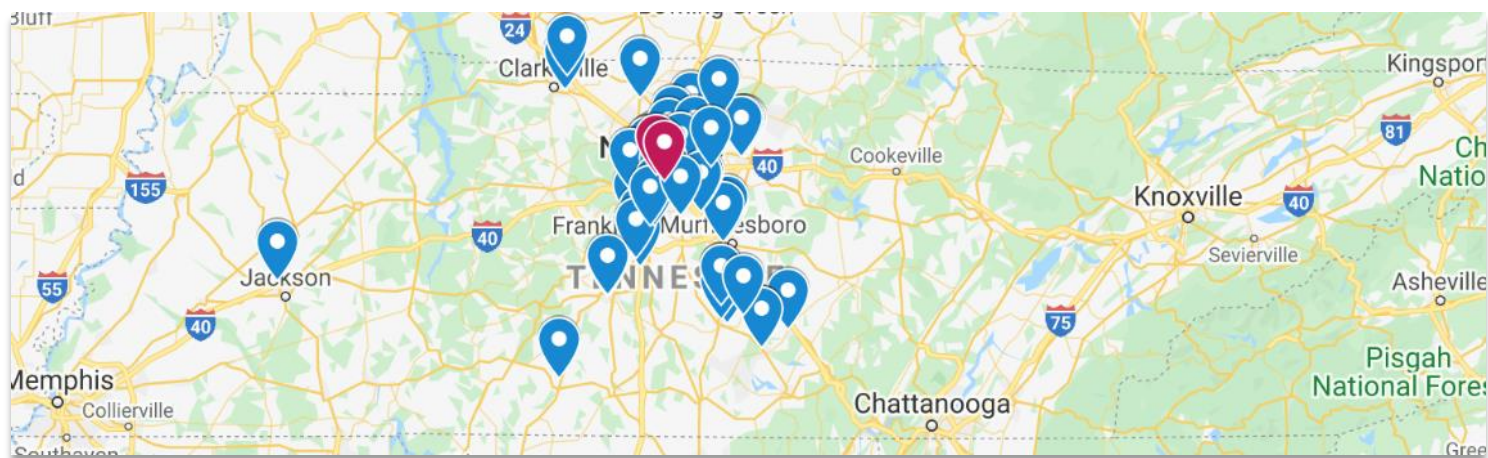


Courier Lockboxes



- Various shapes, sizes
- Thin, high-impact polystyrene or 24 gauge cold-rolled steel
- Insulated with foam and/or Styrofoam
- Available for inside/outside storage
- No guidance, standards or regulations exist

Vanderbilt External Sample Collection Sites



Distance, miles	Lockbox, percent (n)
0-4.9	19.7 (16)
5-9.9	8.6 (7)
10-19.9	24.7 (20)
20-29.9	16.0 (13)
30-39.9	9.9 (8)
40-49.9	4.9 (4)
>50	16 (13)

External Sample Transport and Monitoring

- Car, van, train, (robot, drones, blood bikers) and plane transport
- Various coolers/ “Car Caddies” available
- Specimens not always kept vertical
- Windows, air conditioners, heaters impact temperature
- Temperature, time, agitation, GPS devices available



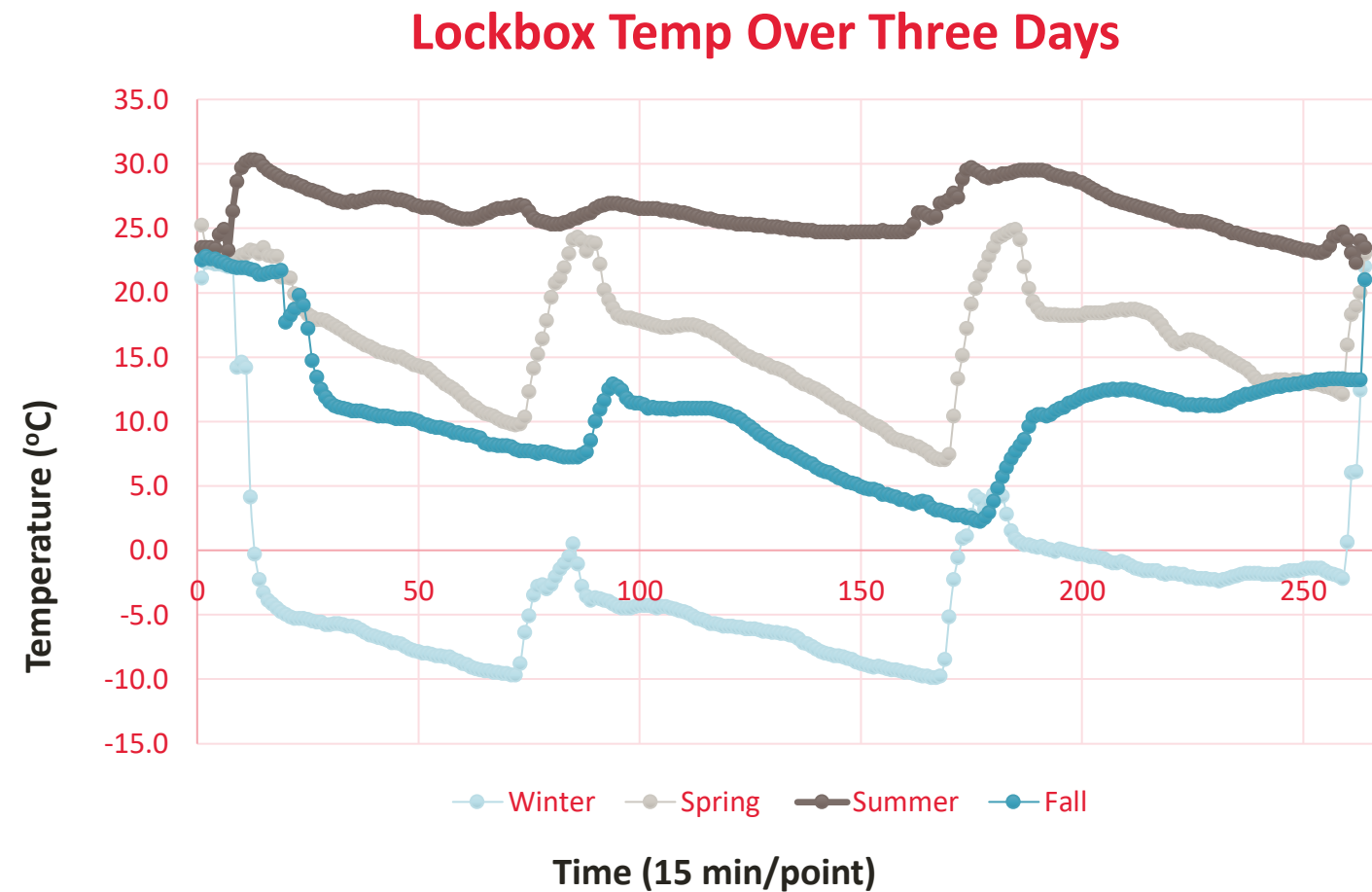
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- **Need for standardization!**

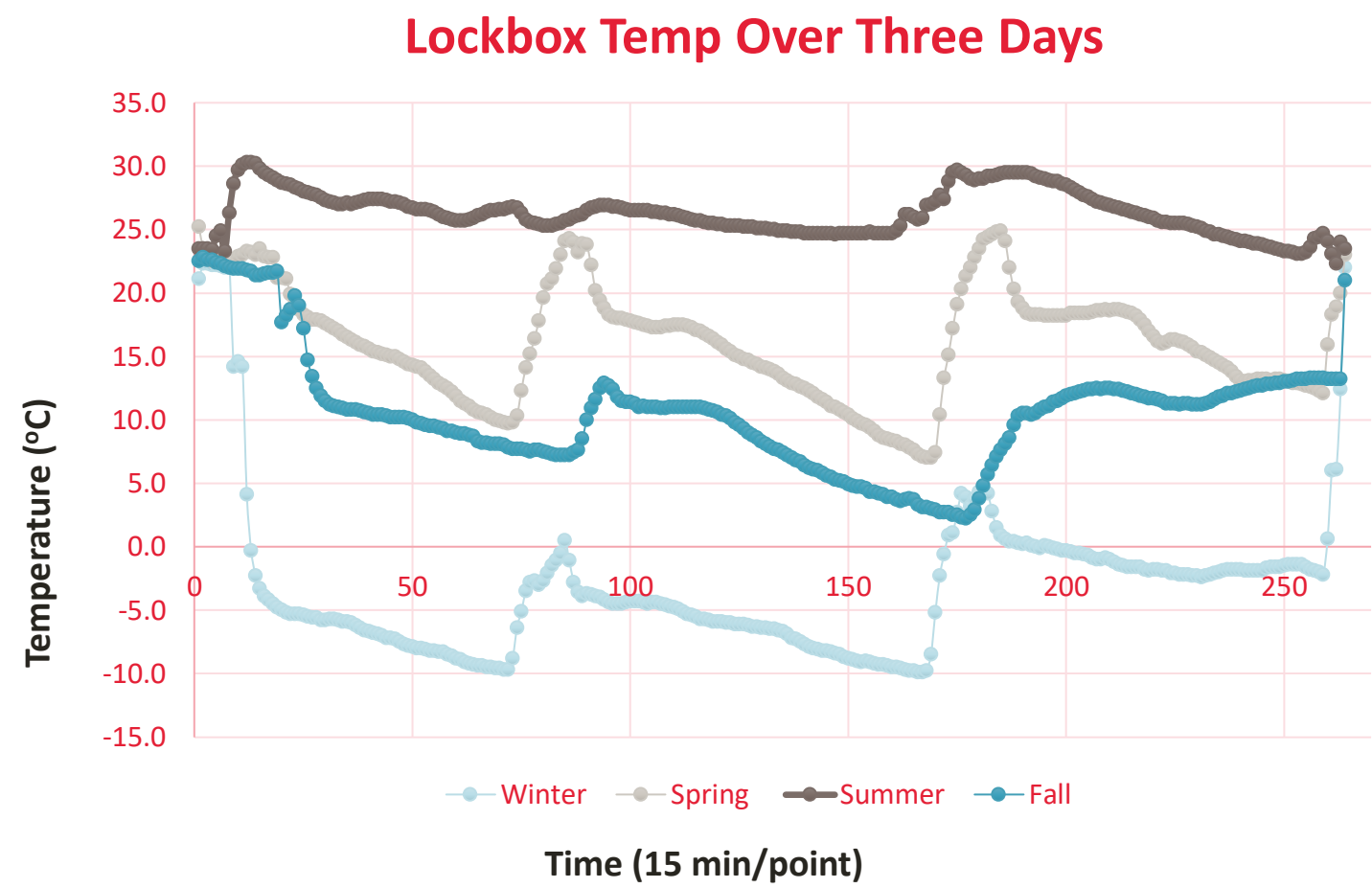


Time and Temperature...

Effects of Seasonal Temp on Steel Lockboxes



Effects of Seasonal Temp on Steel Lockboxes



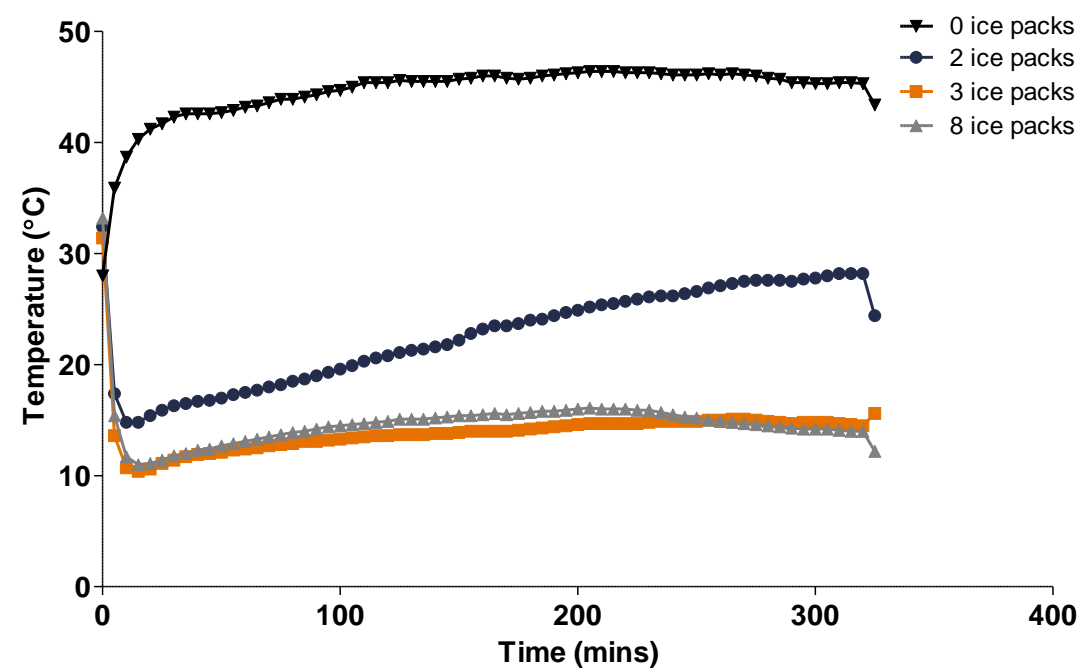
Season	Mean Temp	Temperature Range (Min to Max)	Number of Analytes Outside SCL*
Summer	25°C	21.4 to 32.3°C	9
Spring	16.1°C	7.0 to 25.2°C	11
Fall	10.6°C	2.2 to 22.8°C	7
Winter	-3.1°C	-9.9 to 22.3°C	6

Centrifuged Lithium Heparin Samples
Analytes (n=21): CMP, Lipid Profile, TFTs, Vit D
*SCL: Significant Change Limits (p<0.05)
Common analytes impacted: Glu, K⁺, AST

Lockbox Ice Pack Study



Lockbox Ice Pack Study



Number of Ice Packs	Mean Temp	Temp Range (Min to Max)
0	44°C	28 to 46°C
2	23°C	15 to 32°C
3	14°C	10 to 31°C
8	15°C	11 to 33°C

Courier Lockbox Instructions are Inconsistent

Specific Instructions for Courier Lockboxes							
	Ambient, Chilled, Frozen Shipment	Lockbox Placement	Time Restriction	Temperature Restriction	Cold Weather	Warm Weather	Number of Ice Packs
Lab 1	<u>Yes</u>						
Lab 2	No						
Lab 3	No						
Lab 4	<u>Yes</u>						
Lab 5	No						
Lab 6	<u>Yes</u>						
Lab 7	No						

Labs: Private (n=3), Academic (n=2), Reference (n=2)

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Lab 7	No	No	No	<u>Yes</u>	<u>Yes</u>	<u>Yes</u>	No

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Polymer Lockboxes



Whether it's freezing cold or scorching hot, polymer lockbox keeps your sensitive specimens safe during storage and transport.



When outdoor temperatures fall to 15°F (-9°C), hematology specimens stored in an insulated steel lockbox can freeze and hemolyze in as little as 15 minutes. **Using the polymer lockbox keeps your samples safe for 3.5 hours.**

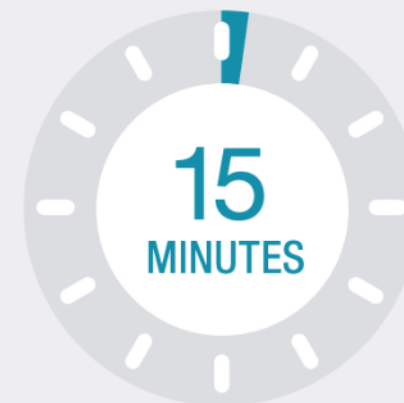


In 100°F (38°C) weather, heat exposure can damage the tube's gel separation barrier, cause proteins to precipitate from the plasma, and render your specimen unusable. **polymer lockbox will keep your samples cool for hours.**

Polymer Lockboxes

Time to Freezing Comparison

15F (-9C) Outside Temperature



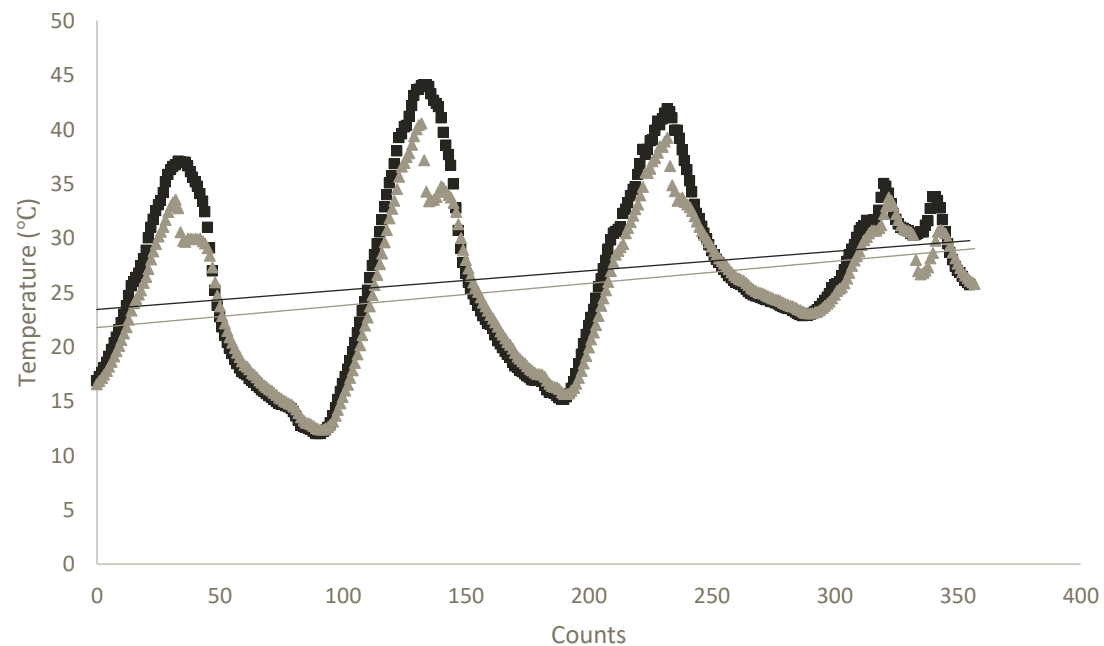
Insulated Steel Box



Polymer Lockbox

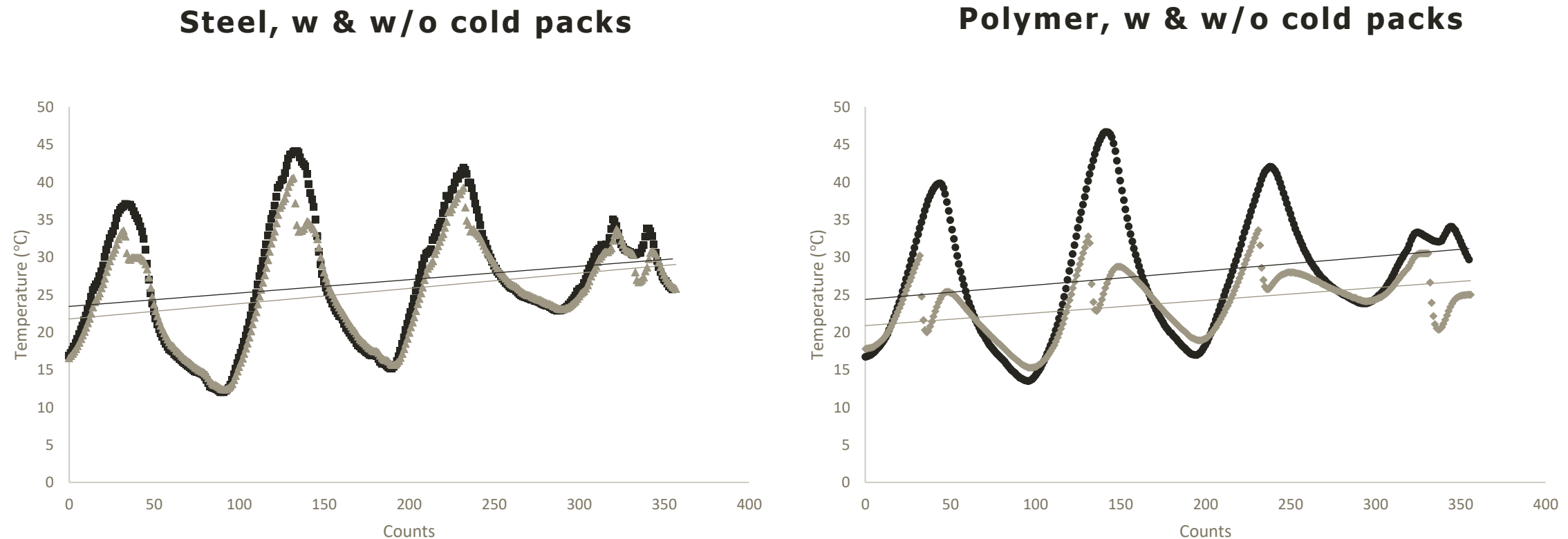
Summer Lockbox Internal Temperature Profiles

Steel, w & w/o cold packs

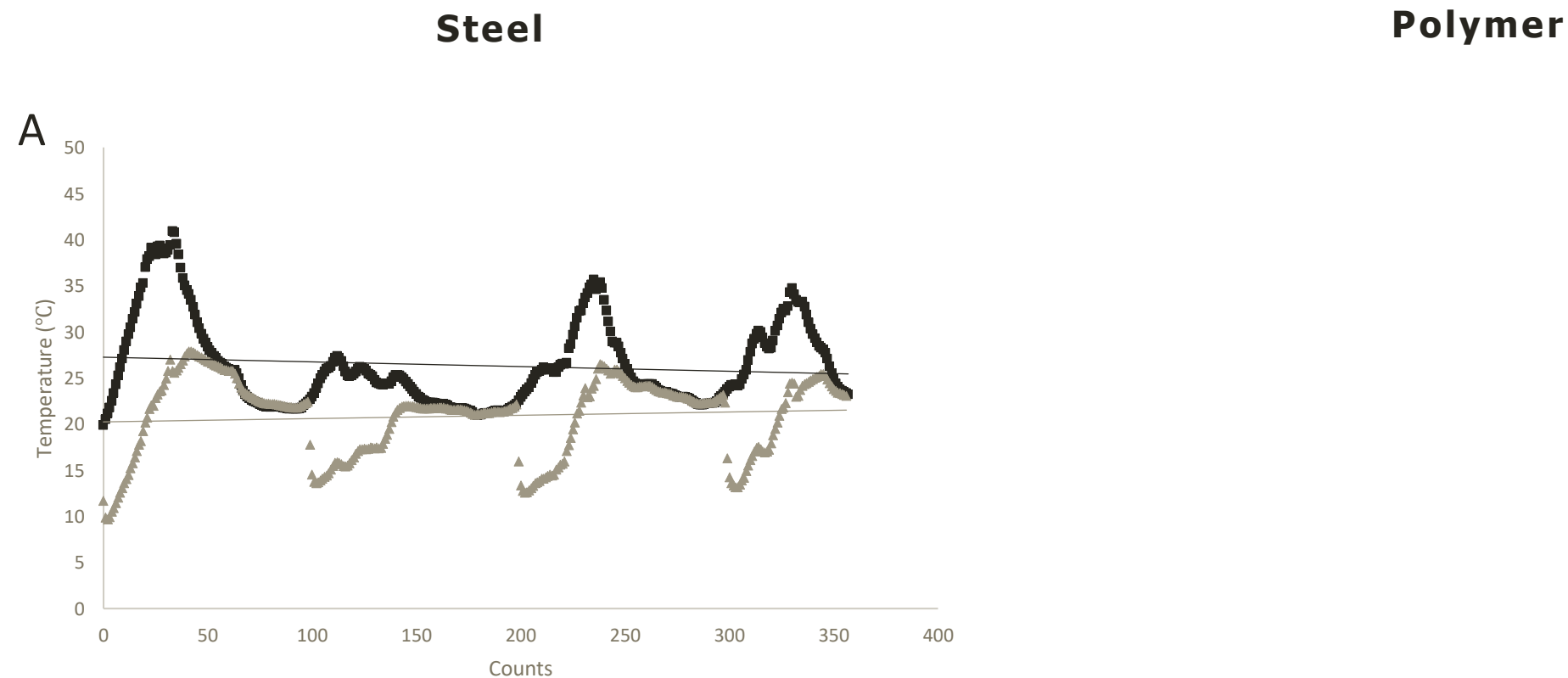


Two cold packs added at 4pm

Summer Lockbox Internal Temperature Profiles

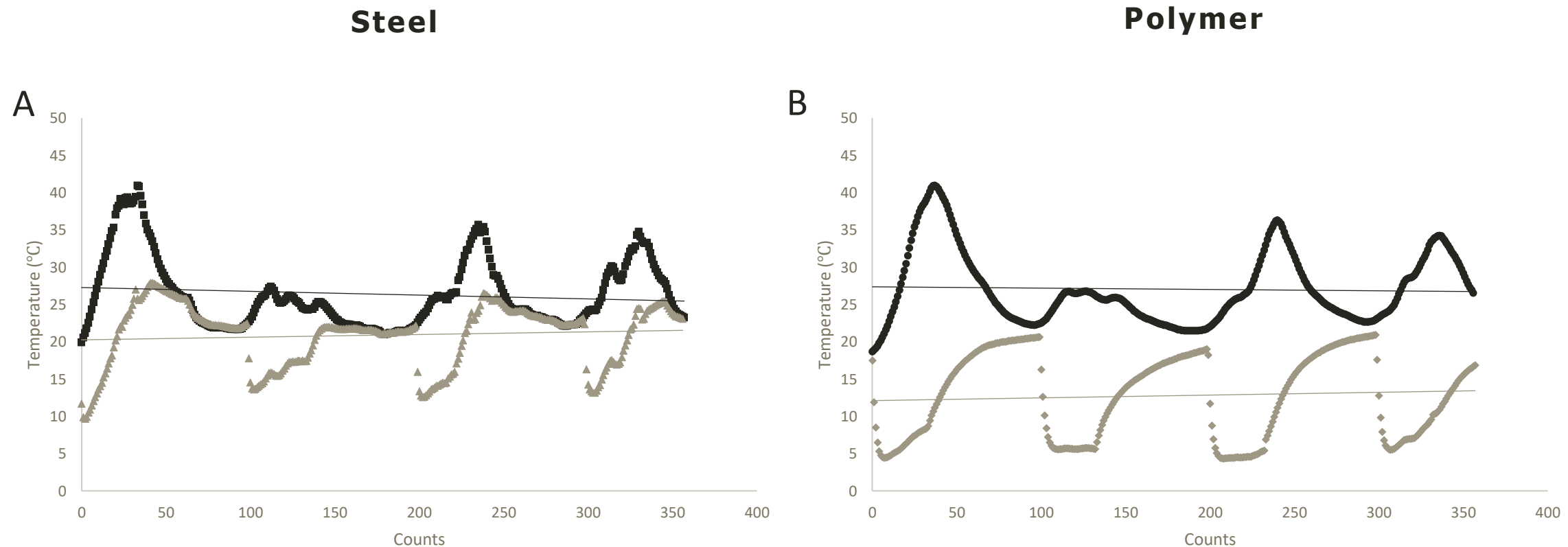


Summer Temperature Profiles w/modified Protocol



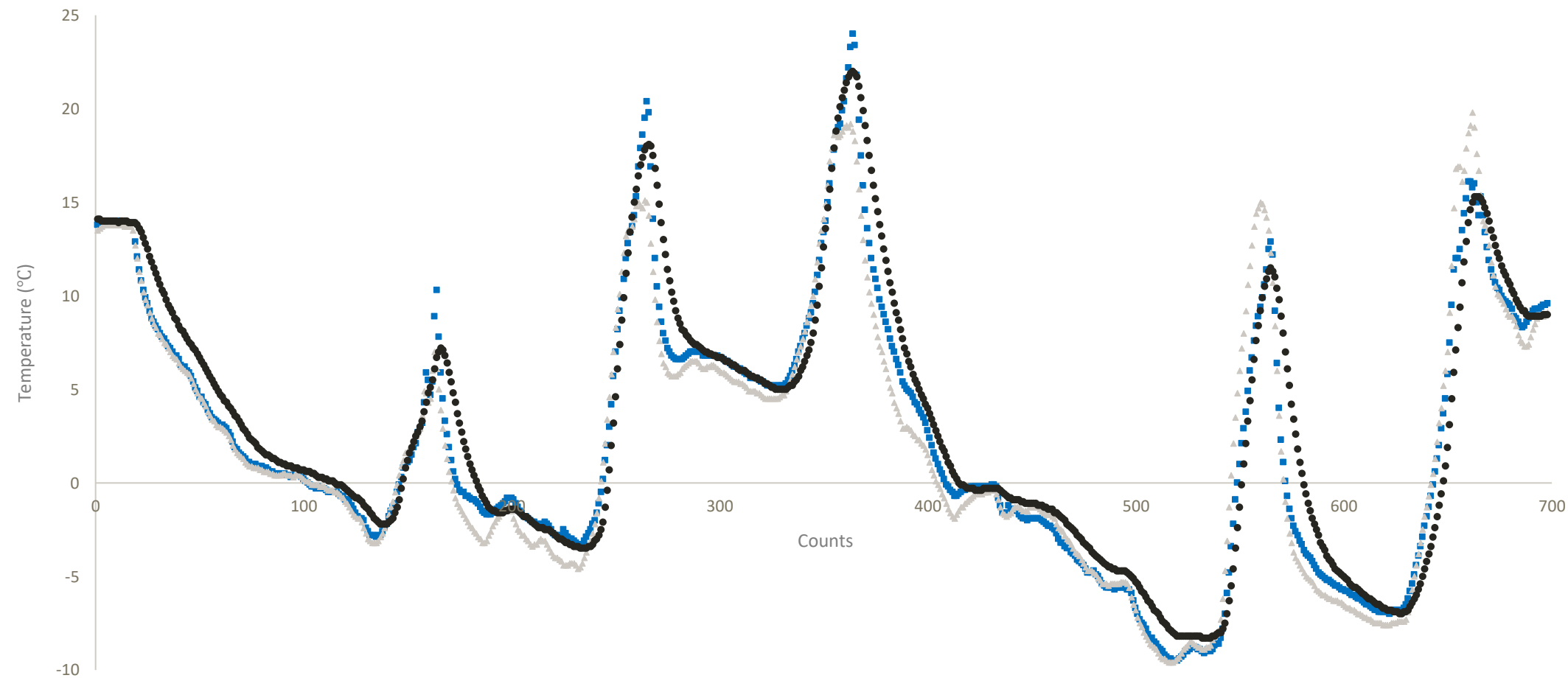
1.) Two ice packs at 8am, 2.) Two cold packs added at 4pm

Summer Temperature Profiles w/modified Protocol



1.) Two ice packs at 8am, 2.) Two cold packs added at 4pm

Winter Lockbox Internal Temperature Profiles



Key:

Blue square = Ambient outdoor temperature

Grey triangle = Steel lockbox temperature

Black circle = Polymer lockbox temperature

Lockbox Inserts

Specimen Insulator

Specimen Insulator for Lock Boxes



- Maintains specimen temperatures inside a lock box
- Gel packs hold temperature for extended periods
- Custom print and fabric colors available

The [Specimen Insulator for Lock Boxes](#) features an insulated pouch combined with specially formulated gel that holds temperature for extended periods of time. [Frozen specimens can be maintained for over 4 hours in 105°F temperatures.](#) Condition the inner gel packs to maintain the specimen temperature desired (frozen, refrigerated or room temperature). [The Specimen Insulator for Lock Boxes](#) is an ideal source of protection for maintaining specimen integrity prior to courier pick up in lock boxes or in courier transit.

Lockbox Inserts

Specimen Insulator

Specimen Insulator for Lock Boxes



Temperature profiles are inexistent!

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Time, Temperature and Location...

Real-Life Examples for Courier Delays

- *“The courier is delayed due to downed trees. Waiting on someone to cut trees from roadway.”*

Real-Life Examples for Courier Delays

- “The courier is delayed due to downed trees. Waiting on someone to cut trees from roadway.”
- “The driver that picks up samples will be delayed. No ETA yet. Vehicle has broken down; Awaiting tow truck.”

Real-Life Examples for Courier Delays

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- “Due to the hard rain and multiple accidents the couriers are going to be delayed with STAT pickups and Routine scheduled pickups.”

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- “The courier driver was not familiar with the route and was delayed in return to lab.”

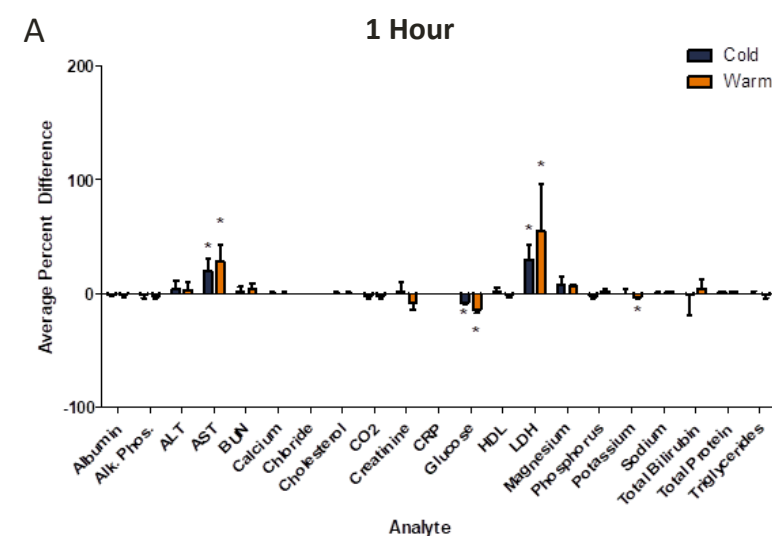
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- “The courier has a flat tire and should arrive around 9:45 PM tonight.”

Real-Life Examples for Courier Delays

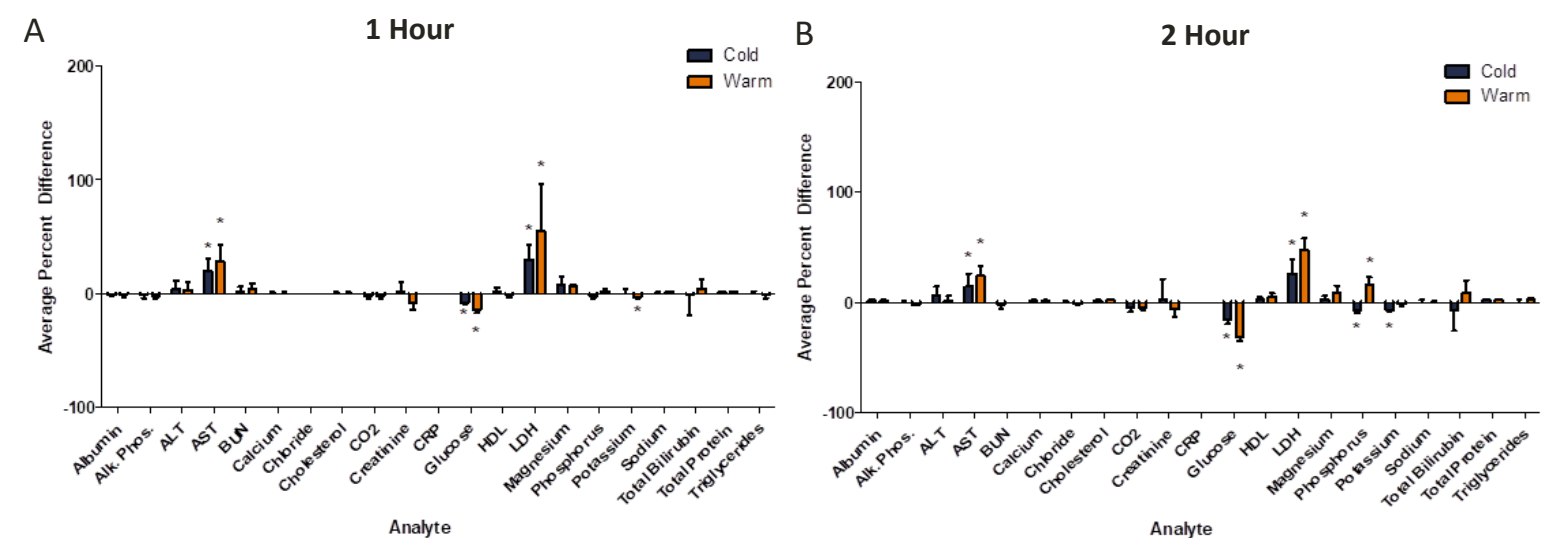
- “The courier is delayed due to downed trees. Waiting on someone to cut trees from roadway.”
- “The driver that picks up samples will be delayed. No ETA yet. Vehicle has broken down; Awaiting tow truck.”
- “Due to the hard rain and multiple accidents the couriers are going to be delayed with STAT pickups and Routine scheduled pickups.”
- “The courier driver was not familiar with the route and was delayed in return to lab.”
- “The courier has a flat tire and should arrive around 9:45 PM tonight.”
- “This morning the courier will be delivering specimens from 3/18/19. Their lab box went missing sometime over the weekend.”

Effects of Short-term Courier Delays: Uncentrifuged



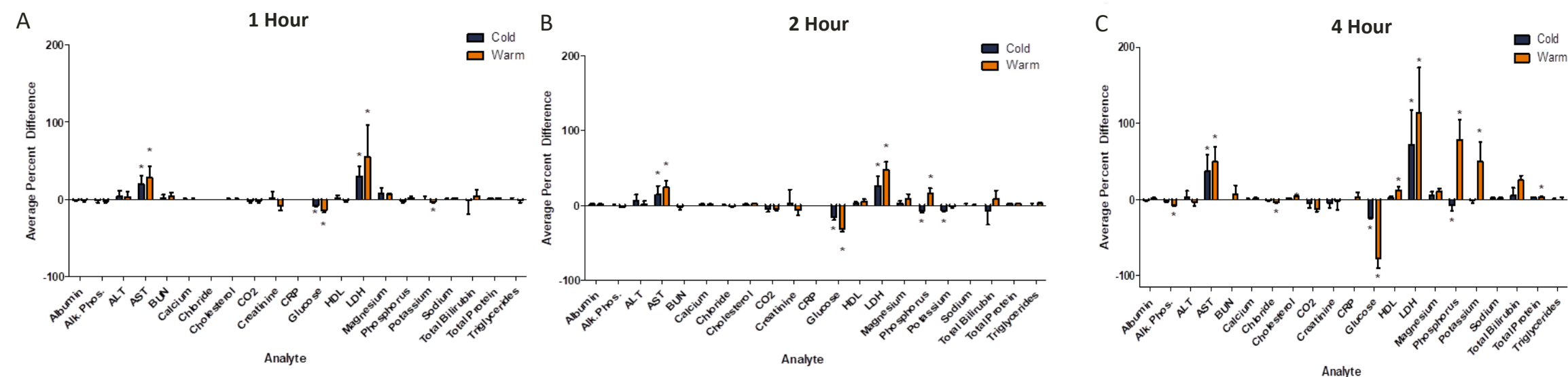
¥Cold = 2 ice packs €Warm = 0 ice packs,
*SCL: Significant Change Limits (p<0.05)

Effects of Short-term Courier Delays: Uncentrifuged



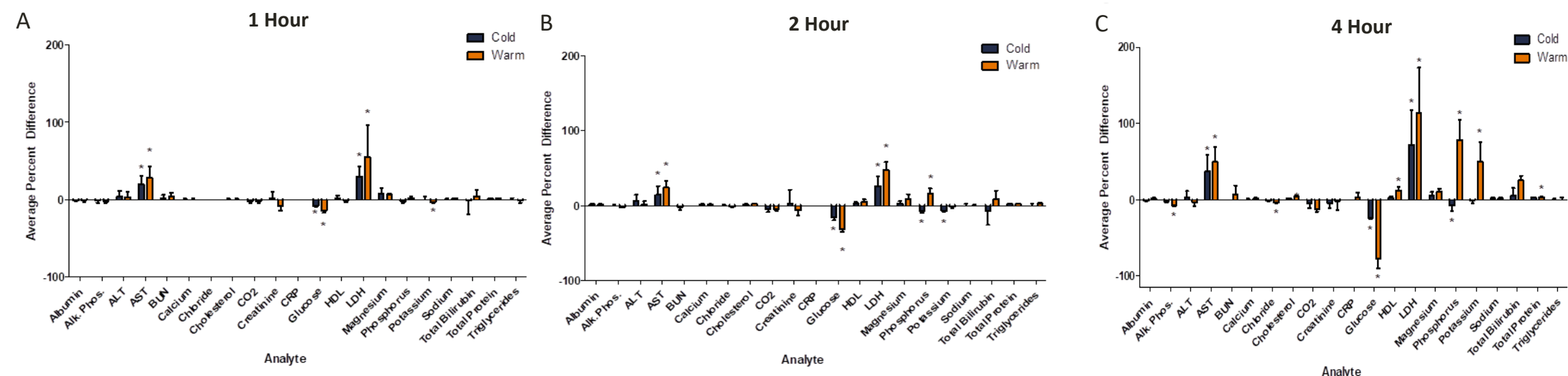
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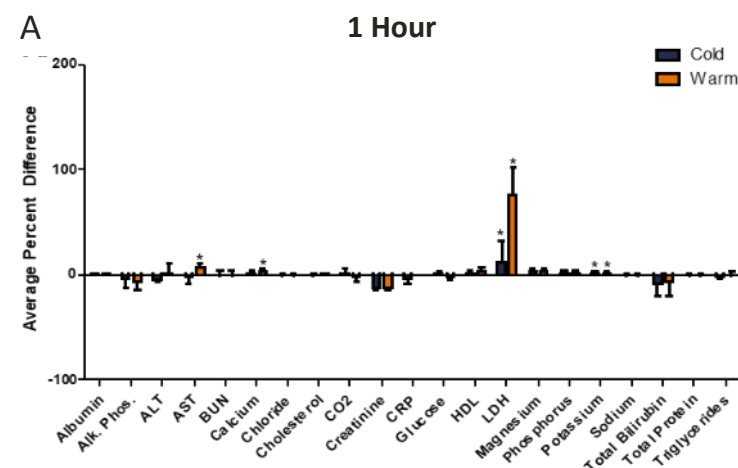
Effects of Short-term Courier Delays: Uncentrifuged



Condition	Mean Temp	Temp Range (Min to Max)	Number of Analytes Outside SCL at 1h	Number of Analytes Outside SCL at 2h	Number of Analytes Outside SCL at 4h
€Cold Lockbox	22.3°C	16.5 to 22.3°C	3	5	4
¥Warm Lockbox	42.6°C	34.4 to 46.9°C	4	4	10
Outdoors	40.4°C	28.2 to 44.0°C	NA	NA	NA

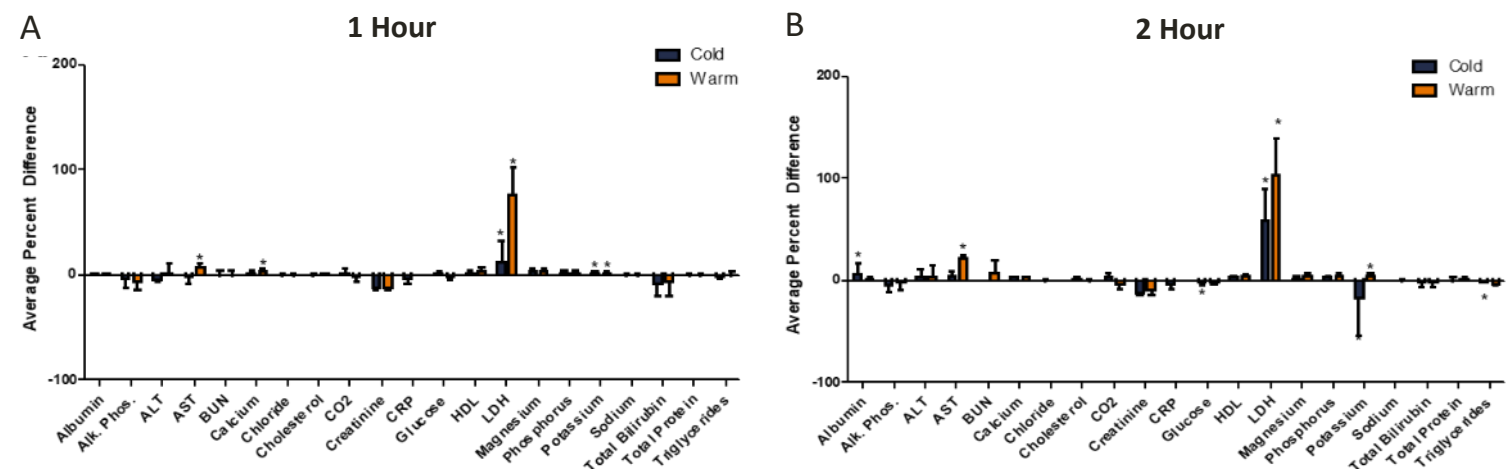
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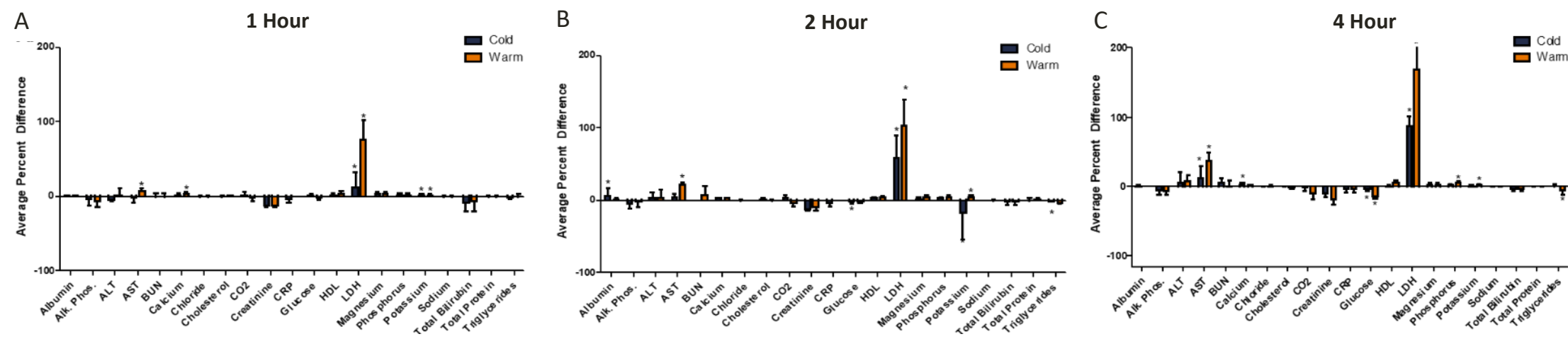
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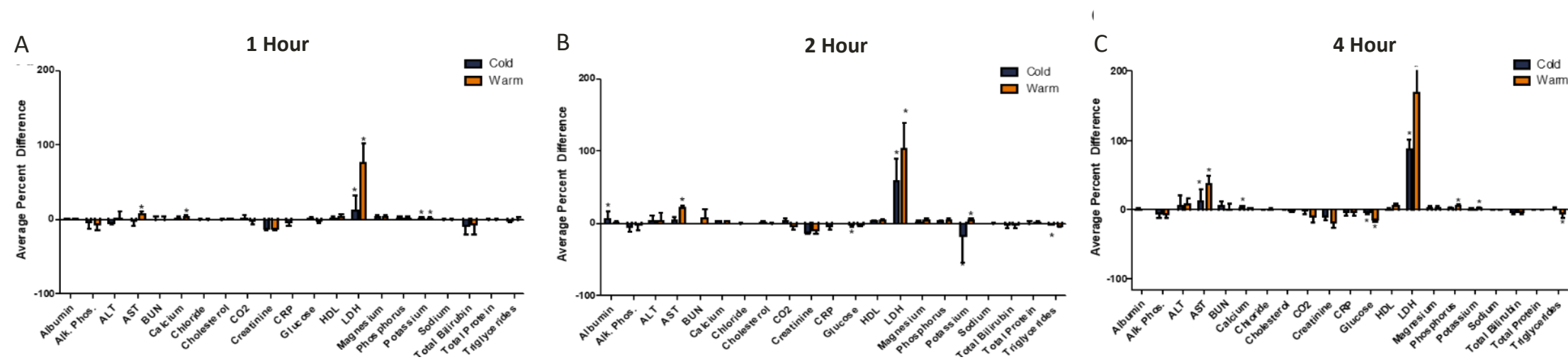


Effects of Short-term Courier Delays: Centrifuged



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Effects of Short-term Courier Delays: Centrifuged



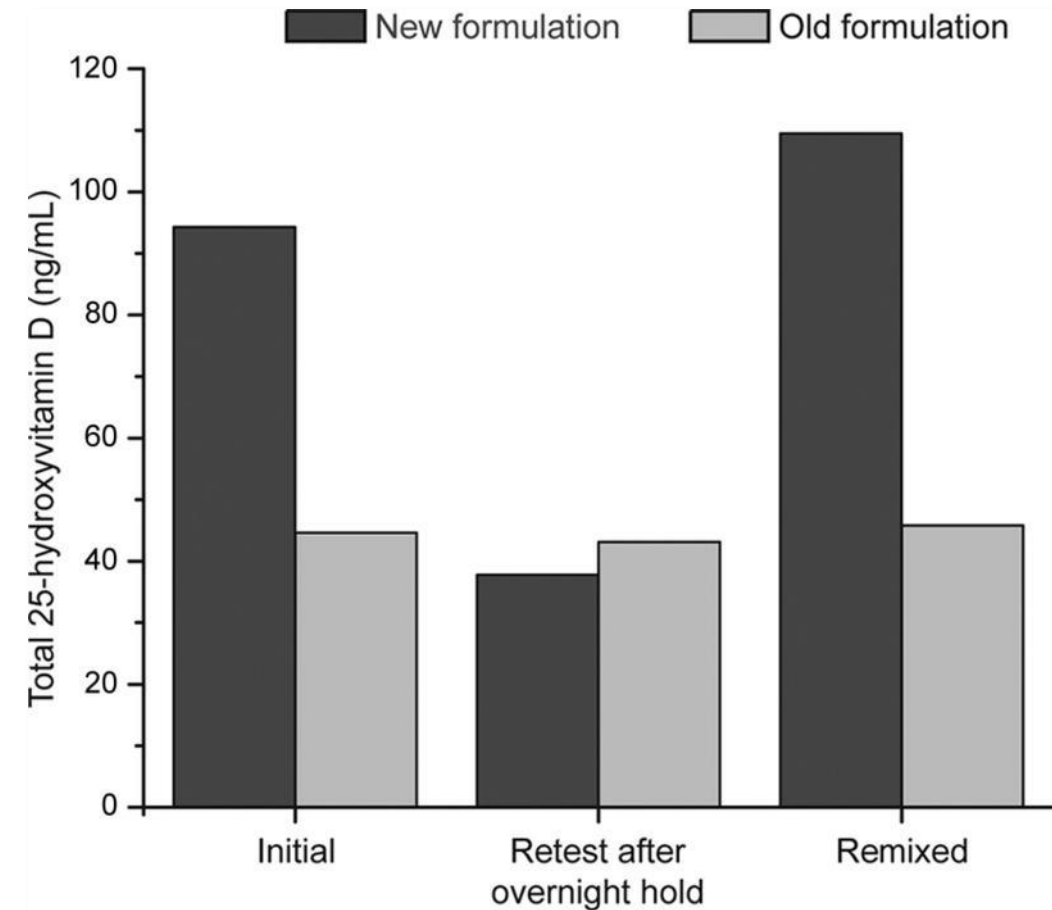
Condition	Mean Temp	Temp Range (Min to Max)	Number of Analytes Outside SCL at 1h	Number of Analytes Outside SCL at 2h	Number of Analytes Outside SCL at 4h
€Cold Lockbox	18.0°C	12.2 to 23.0°C	2	5	4
¥Warm Lockbox	35.2°C	25.9 to 40.8°C	4	3	6
Outdoors	37.9°C	27.2 to 46.3°C	NA	NA	NA

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Agitation

Agitation/Shock Events are a Source of Error

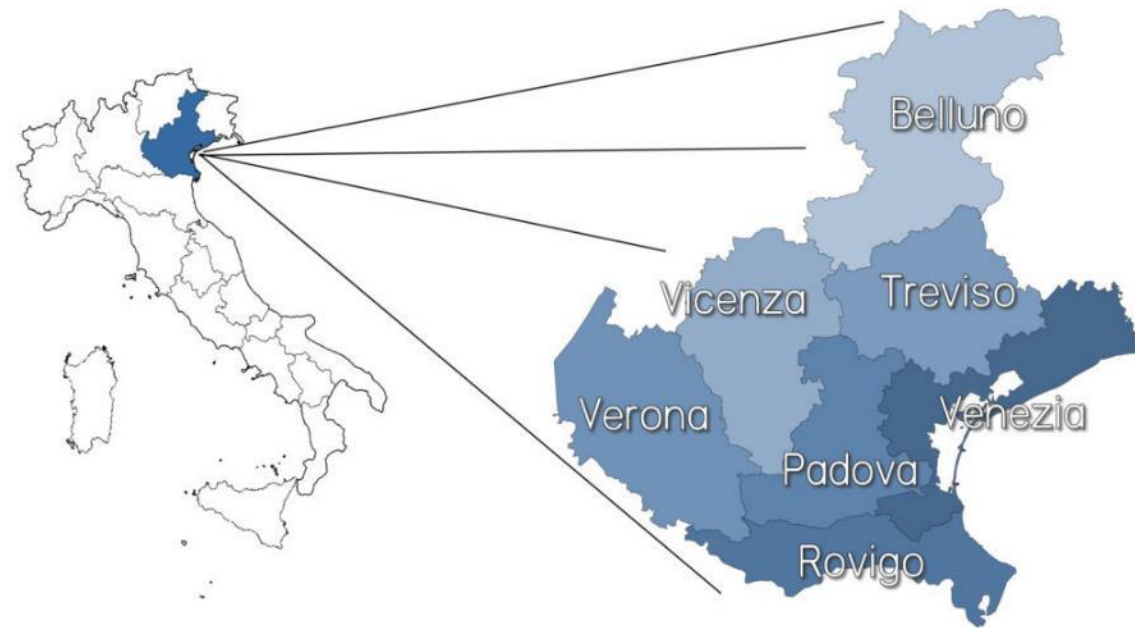
- Discrepant patient results for Total Vitamin D
- Both specimens collected in Plasma Separator Tubes
- PST samples susceptible to cell debris, microclots, and other particulate matter
- New reagent formulation *without* pretreatment step
- Do “shock events” need to be monitored in the outpatient setting?



Solutions

Integrated System for Sample Transportation

- Integrated system
 1. Tertiary container
 2. Secondary container
 3. TempStick/data-logger
 4. Mission starter
 5. System manager



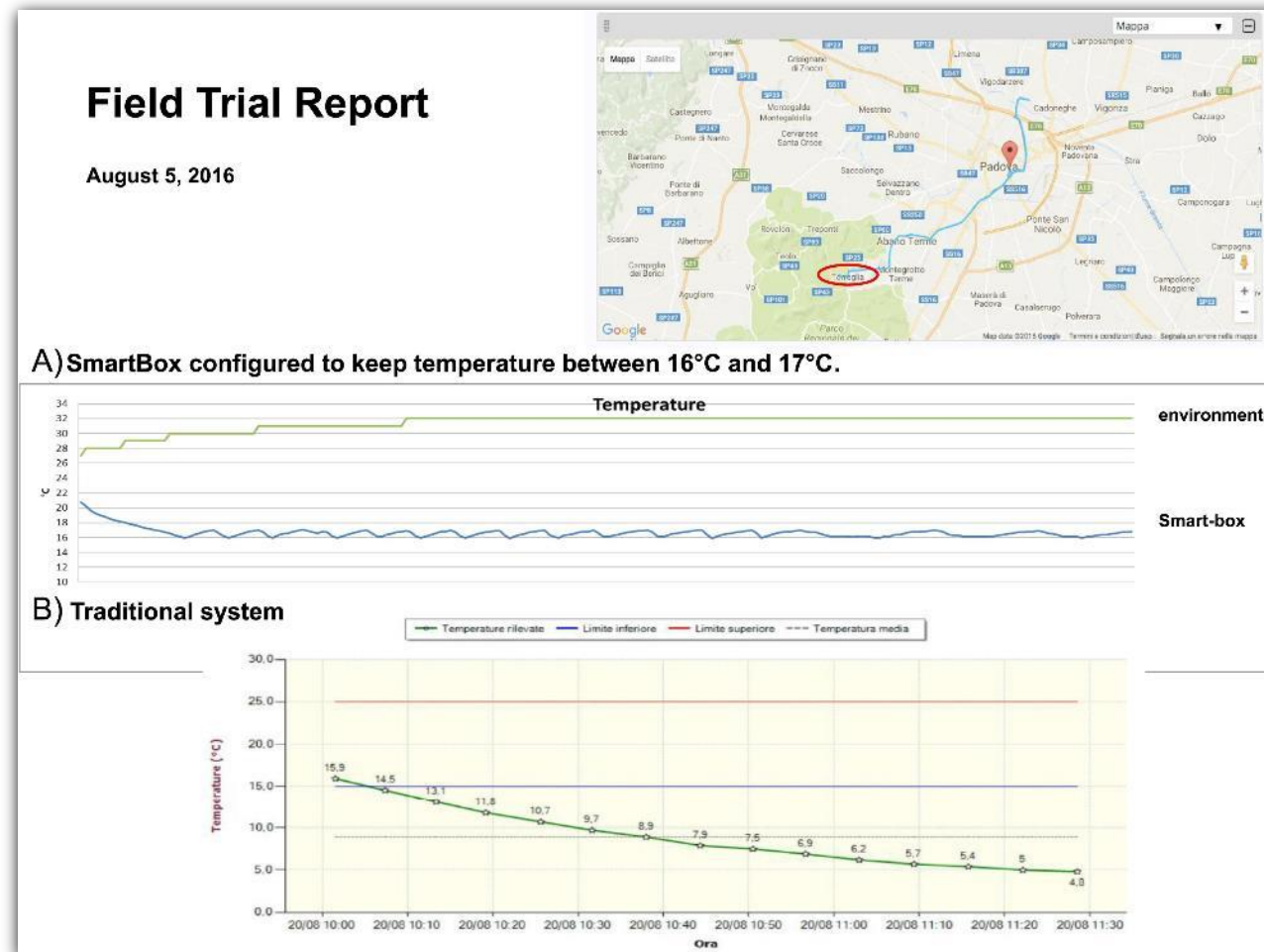
- Established SOPs
- Monitored number of transportations, acceptable temps ($<20^{\circ}\text{C}$), unacceptable temps ($>25^{\circ}\text{C}$), acceptable transport $<3\text{h}$

“Smart-Boxes” for Sample Transportation

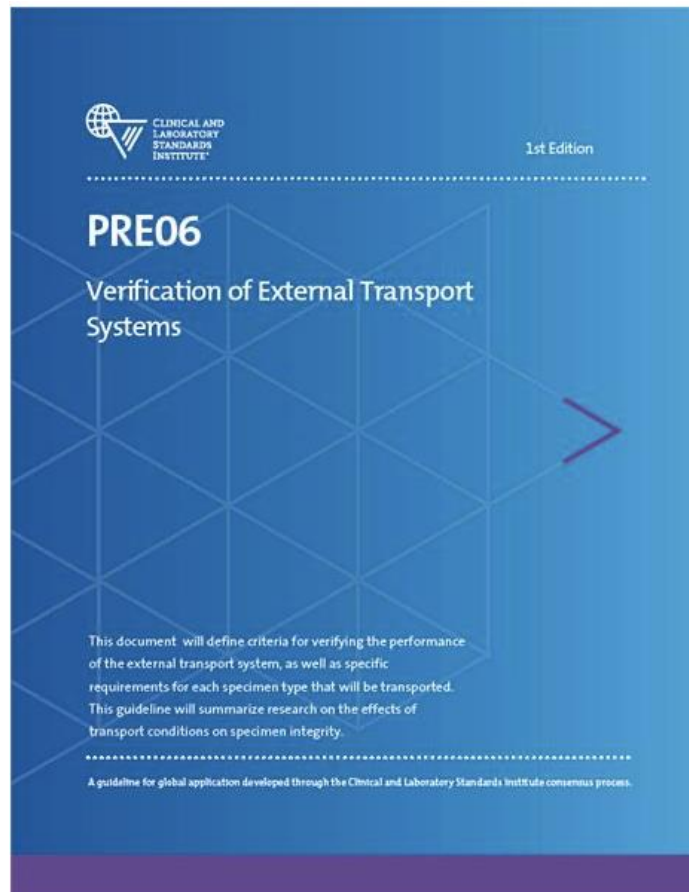
Future Box?



“Smart-Boxes” for Sample Transportation



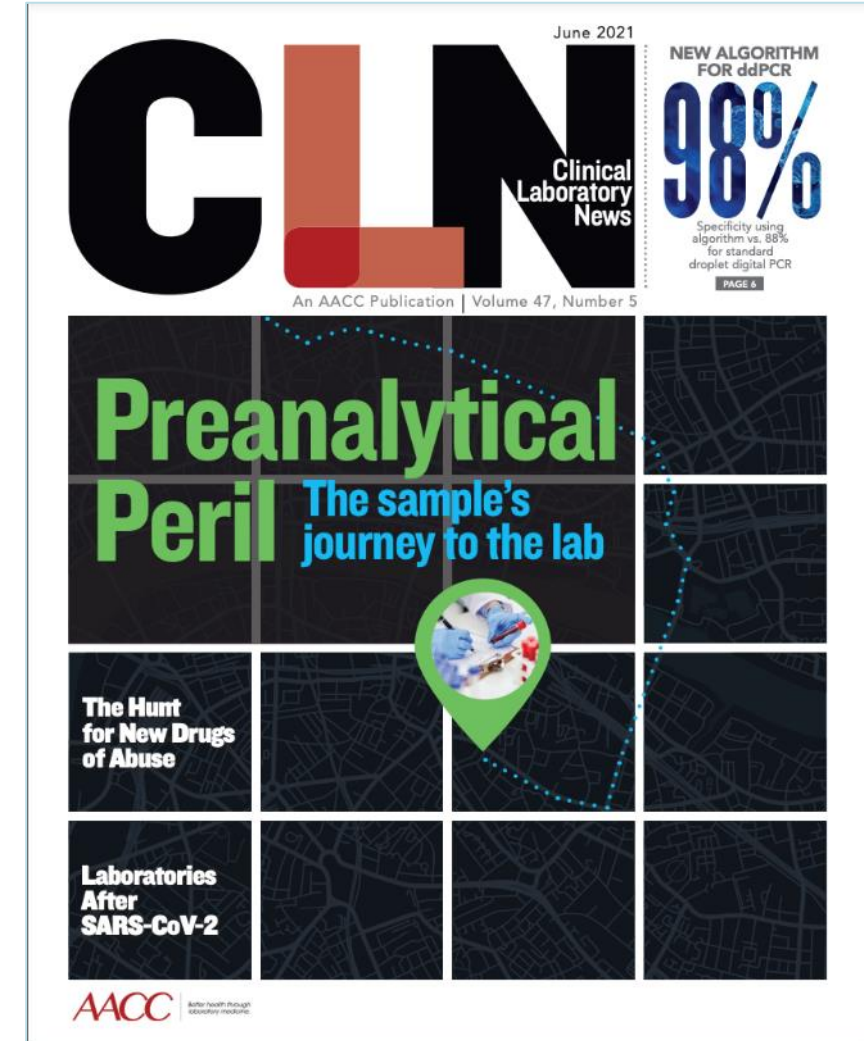
PRE06: Verification of External Transport Systems



- **CLSI, 1st Edition**
- Define criteria for evaluating the performance of your external transport system(s)
- Specific requirements for each specimen type
- Temperature fluctuations, temperature extremes; agitation/shock events

Summary

1. Specimen transport maps contain several critical steps (before/after courier pick-up)



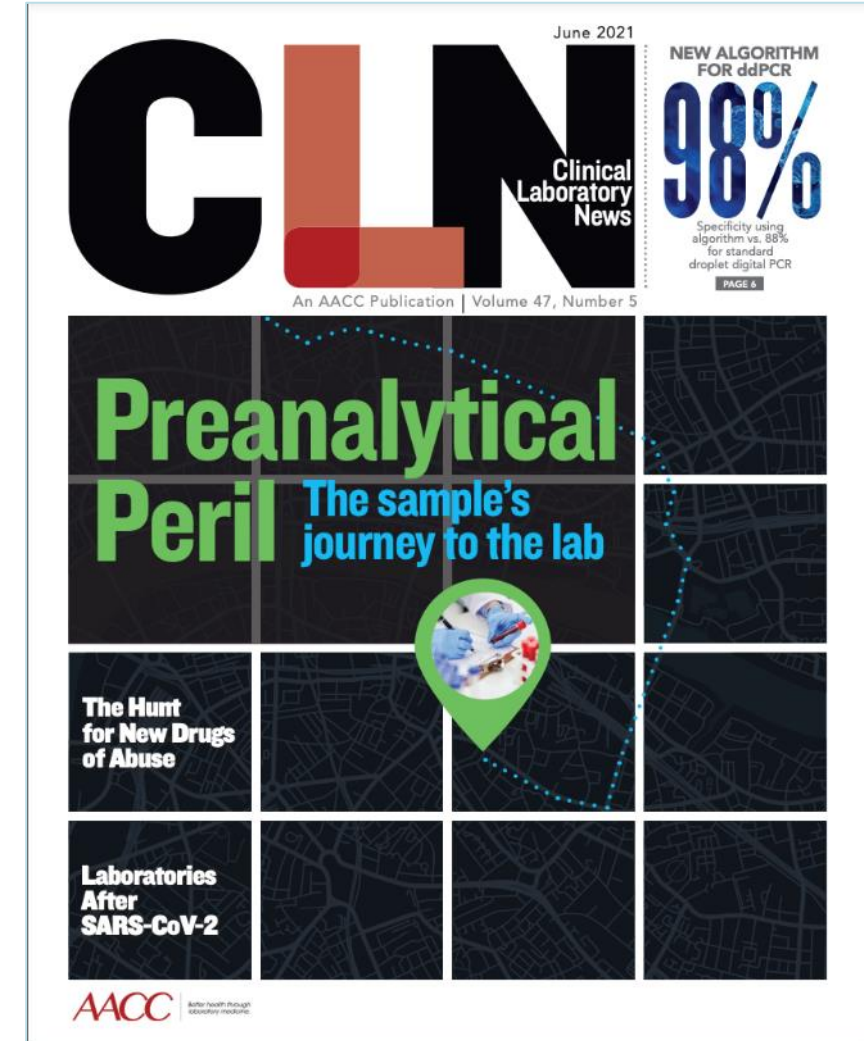
Summary

1. Specimen transport maps contain several critical steps (before/after courier pick-up)
2. There are four main monitoring conditions for sample transport
 - Time
 - Temperature
 - Agitation/Shock Events
 - Location



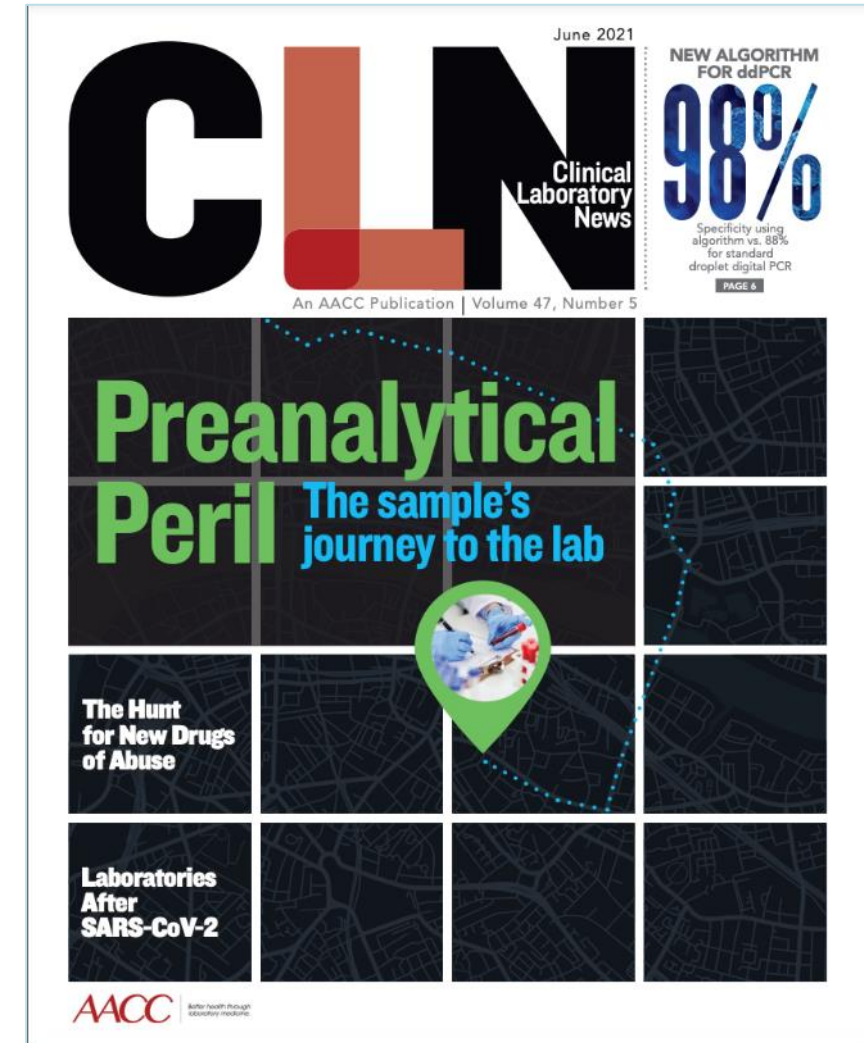
Summary

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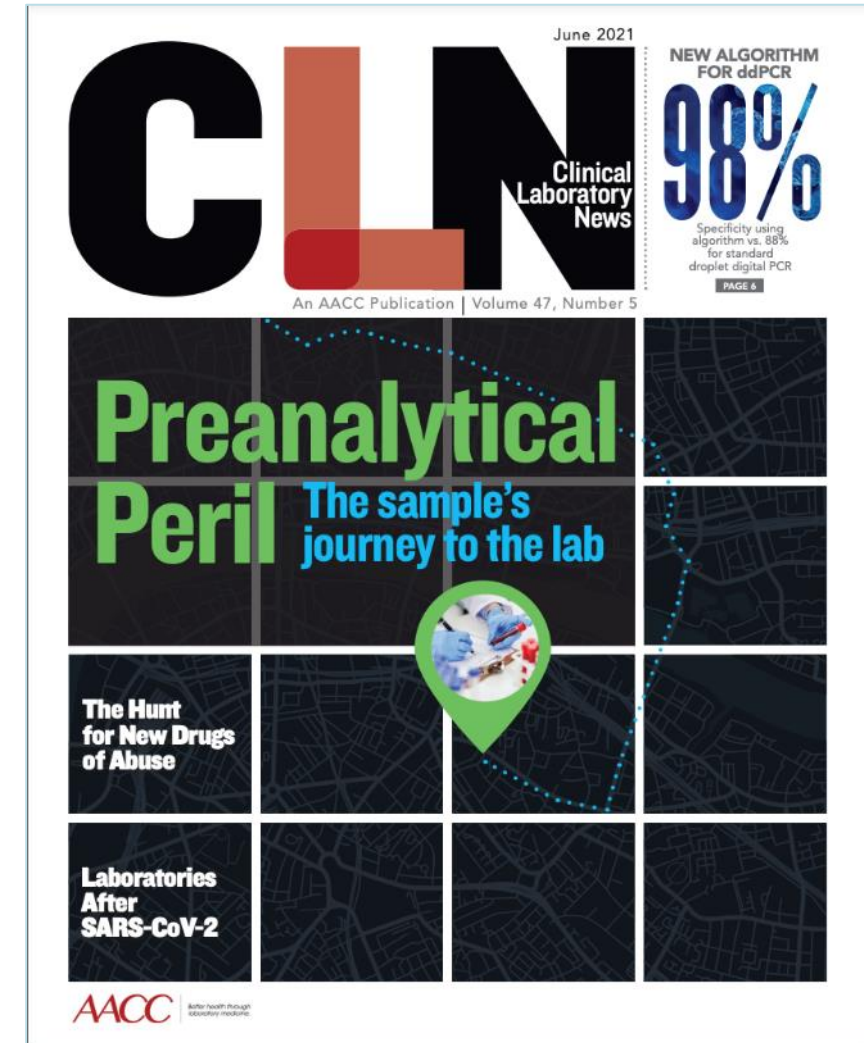
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Summary

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2. There are four main monitoring conditions for sample transport
 - Time
 - Temperature
 - Agitation/Shock Events
 - Location
3. Courier lockbox instructions are inconsistent between institutions
4. Integrated sample transport systems can reduce unacceptable sample conditions
5. Standardization is essential



Questions?
