MAYO CLINIC LABORATORIES

Capillary Puncture vs. Venipuncture: Advantages and Limitations to Using Capillary Blood

Brad S. Karon MD PhD
Professor of Laboratory Medicine and Pathology
Chair, Division of Clinical Core Laboratory Services

Disclosures

Relevant Financial Relationship(s):

Nothing to Disclose

Off Label Usage:

Nothing to Disclose

Outline

- Capillary vs venous blood
- Use of capillary blood and arterialized capillary blood for infants and children
- Use cases for capillary blood in adults
- Summary

Blood circulation

- Heart → lungs → heart → arteries → capillaries (deliver oxygen/glucose to tissue, pick up waste) → veins → heart
- Heart: blood sampled directly from heart in ICU, cath lab
- Lungs: No option to sample capillary bed in lungs
- Arteries: Peripheral arteries can be accessed when needed
- Veins: Easy to access, few differences from arterial blood
- Capillaries: Content reflects local tissue exchange, partially venous and partially arterial in content, cannot be directly accessed (too small)

Venous blood

- Reference sample for most laboratory testing
  - Whole blood removed directly from vein by venipuncture or catheter
  - Easy to obtain (compared to arterial)
  - Reflects circulating concentration of cells, analytes, proteins in blood
  - Defined by ADA as reference type for diabetes diagnosis (venous plasma glucose, glucose concentration available to brain)
- Situations requiring arterial blood or possible differences
  - Oxygenation status: requires arterial blood for pO2/sO2 with exception of arterialized heelstick for infants
  - Ammonia and lactate: Some data to suggest arterial better reflection of disease state, differences most often minimal

Capillary blood

- Capillaries cannot be directly accessed (sample capillary bed)
- “Capillary blood” is mixture of arterial blood, venous blood, intracellular fluid (cells break during capillary puncture), and interstitial fluid (not blood, fluid that bathes tissue)
- Cellular content of K, AST, LDH several-fold higher than circulating blood
- Many analytes reach equilibrium between interstitial fluid and circulating blood, but not all things we want to measure
  - No hemoglobin or cellular material (amazingly Hgb and cell counts work OK, but more variability in capillary blood)
  - Glucose lag after eating (venous, then capillary, then interstitial)

Mayo Clinic guidelines for capillary collections

- Heelstick up to 12 months or 20 lb
- Fingerstick after 12 months or 20 lb
- If heelstick depth not to exceed 2 mm

Capillary sampling limitations: biochemical testing

- Blood gas and acid base
- Heating heel of infant with “arterialize” capillary blood
- pO2 of arterial blood normally 80-100 mm Hg (assume adequate oxygen exchange in tissues)
- pO2 of venous blood normally 40-50 mm Hg (no information about oxygen delivery or exchange to tissues)
  - Can assess acid-base status, indirectly respiratory status thru pCO2, but not oxygenation with venous blood gas
- “Arterialized” heelstick samples in adults can provide information on oxygen exchange thru analysis of pO2 (separate reference intervals required)

Capillary sampling limitations: biochemical testing

- Fingerstick capillary blood gas can provide information equivalent to venous blood gas (acid-base status, indirect information about respiratory status thru pCO2)
- Fingerstick capillary pO2 does not correlate with arterial blood pO2, provides no information on oxygenation

Capillary sampling limitations: biochemical testing
Hemolysis and potassium

- Measurement of potassium from capillary samples
- Patel et al, 1983 Arch Dis Child 1988;63:752-3
- 40 neonates with art line and capillary blood gas and electrolyte measurements
- Capillary K ran 1.2 ± 1.0 higher than art line after 2 mL flush
- Capillary K higher than arterial, but why?

Studies of hemolysis in capillary puncture

- Algeciras et al., Clin Biochem 2007;40:1311-6
- Studied plasma Hgb level in 151 infant capillary punctures
  - 45 samples collected by 14 trained outpt phleb (Group 1)
  - 37 samples collected by 5 re-trained outpt phleb (Group 2)
  - 69 samples collected from inpatient nursery (Group 3)
    - Group 1 median Hgb 128 mg/dL
    - Group 2 median Hgb 164 mg/dL
    - Group 3 median Hgb 156 mg/dL (not stat sig)
      - Overall mean Hgb 162 mg/dL
- Capillary samples contain more free hemoglobin (hemolysis) than venipuncture, can't train that away

Studies of hemolysis in capillary puncture

- Meites et al, Clin Chem 1981;27:875-8
- Studied mean plasma Hgb level in 417 capillary punctures, monolet lancet and lithium heparin microtainer, 15 trained technologists
  - Typical venous free Hgb < 50 mg/dL

Age	n	Mean Hgb
0-13 d	176	390 mg/dL
14d- 3 mo	47	220 mg/dL
3 mo – 2 yr	49	160 mg/dL
> 2 yr	145	150 mg/dL
Overall	417	260 mg/dL

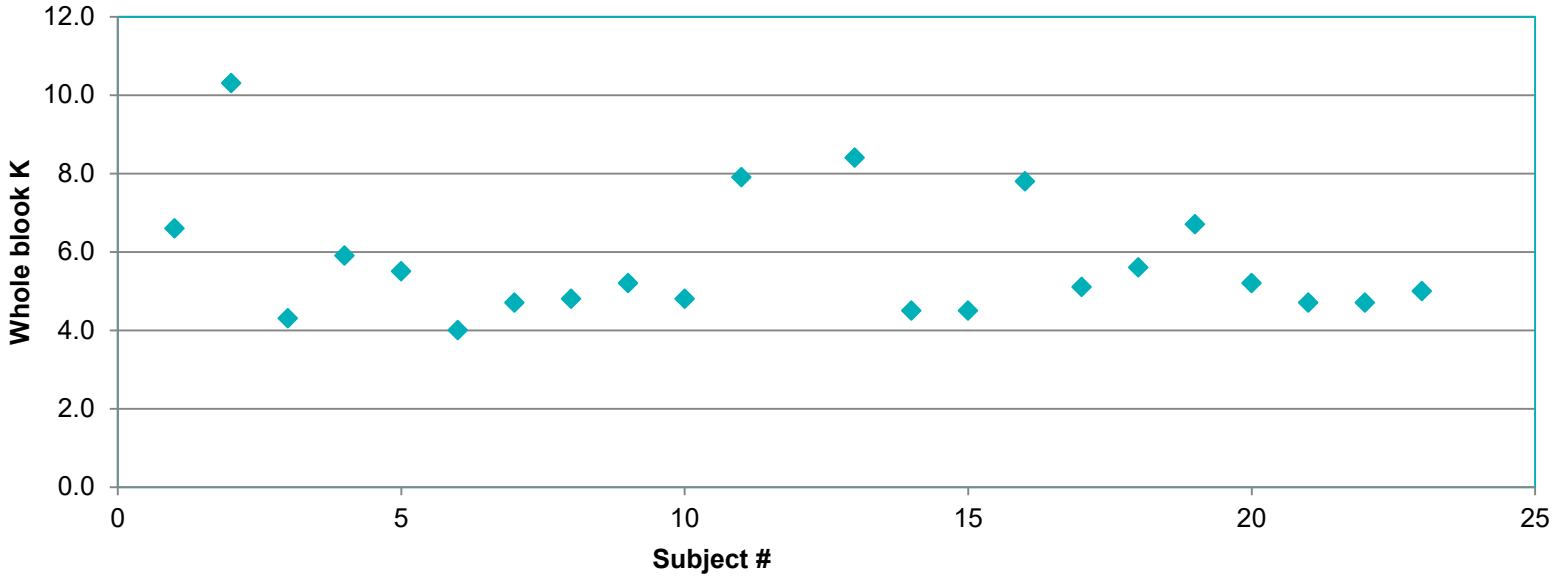
Effect of hemolysis on capillary K

- Oostendorp et al, Arch Pathol Lab Med 2012;136:1262-65
- Compared avg K to H index (semi-quant) for 332,760 venous and 2620 capillary samples (ED and ICU excluded)

Venous samples			Capillary samples	
H index	% samples	Avg K	% samples	Avg K
0	81.1	~ 4.0	37.5	~ 4.0
1	13.6	~ 4.2	42.2	~ 4.5
2	4.3	~ 4.5	10.6	~ 5.0
3	0.4	~ 4.8	3.9	~ 5.2
4	0.2	~ 5.0	2.4	~ 5.5
≥ 5	0.1	~ 5-6	3.0	~ 6.0

Capillary K, blood gas samples

- Mayo Clinic cap gas reference interval study (n=22)
  - Heal warming, capillary tube collections, hand transport



- Mean K = 5.7 mmol/L
- Range 4.0 – 10.0
- Made decision not to report K with capillary blood gas

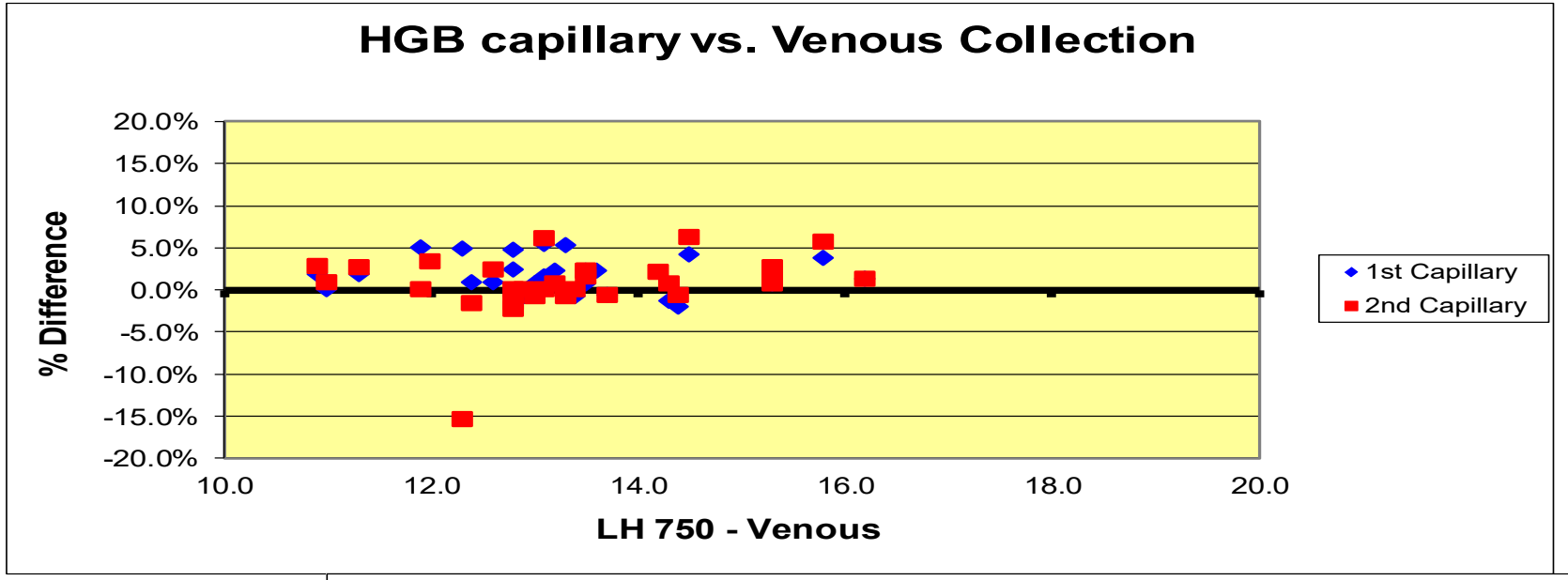
Capillary K (hemolysis) conclusions

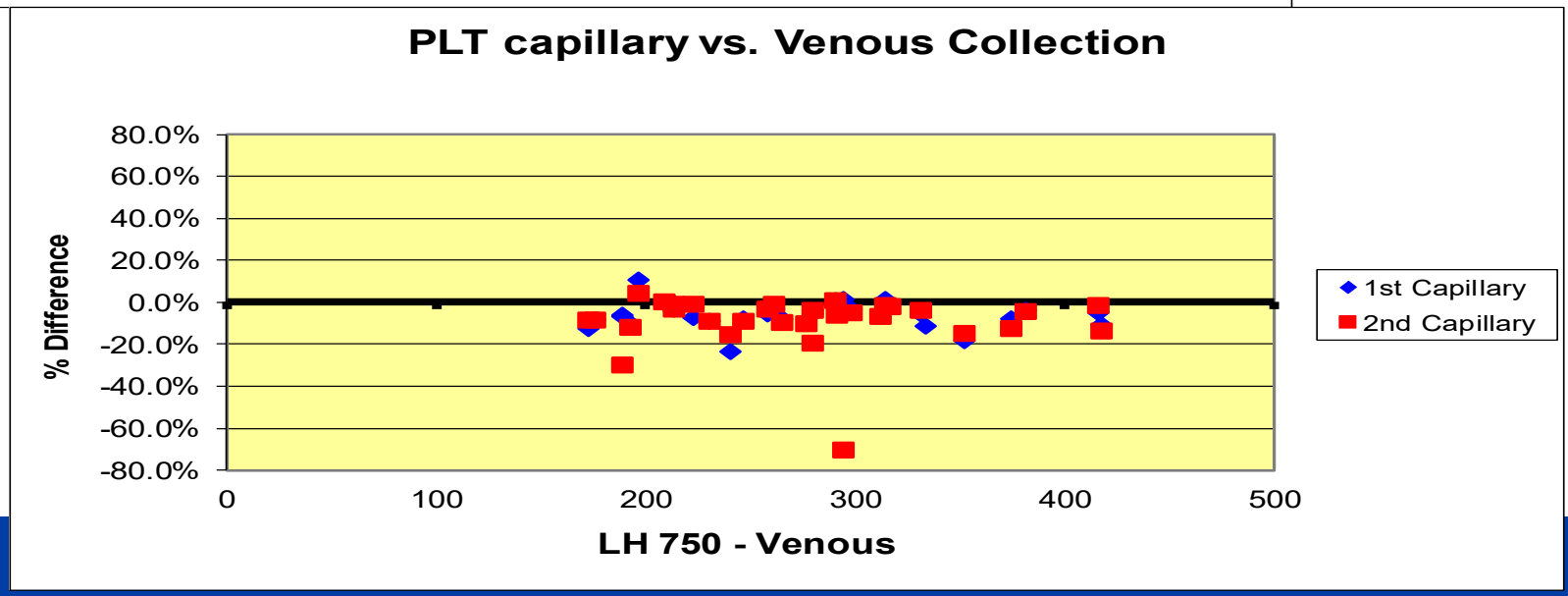
- Capillary samples contain more free Hgb (hemolysis) than venipuncture samples
- For a given amount of free Hgb, raise in K higher for capillary compared to venous samples
  - Release of K from cells and tissue during capillary puncture?
- Measurement of capillary K best limited to equipment with H index measurement
  - Even then lab should consider different H index cut-off for capillary samples, or apply cut-off strictly
- Biochemical tests with analytic interference (direct bilirubin) from free hemoglobin also rejected frequently with capillary samples

Cell counts using capillary blood

- Variability due to variable amount of interstitial fluid (no cells) in specimens
- Capillary samples more prone to clot due to time to collect and method of collection
  - Fully clotted specimens rejected by lab
  - Partially (micro) clotted specimens can have erroneous cell counts reported
  - Use of a transfer device (device that introduces EDTA into specimen before it reaches the tube) may help

Capillary vs venous cell counts (using transfer device)





Mayo approach to capillary collections for kids

- If ≤ 1 cc blood needed, phlebotomists given script to ask parent whether capillary or venipuncture collection preferred
- Some other institutions successful at getting over 1 cc blood via capillary collection
- Mayo practice
  - Capillary heelstick bilirubin very common
  - Capillary heelstick CBC fairly common, data suggests higher than desirable (5-6%) redraw rate for both due to clotting
  - Fingersticks in children not common (capillary blood gas in children)
  - Newborn screening

What tests should not be collected capillary for infants and children?

- K very high in heelstick samples
- Lactate tends to run high, caution
- Other blood gas and electrolytes OK
- Liver function (disease) tests not evaluated
- Most other chemistries OK, reject many direct bilirubin due to hemolysis analytical interference
- CBC with diff OK
- Coag probably not (see adults, very limited application infants and children)

Capillary sampling: Adults

- Capillary sampling limited to situations requiring frequent sampling, rapid turnaround time, or sample collection in non-traditional settings
- Primary uses capillary glucose testing and point of care INR monitoring

Capillary glucose measurement

- Common at home and in hospital
  - At home: Self-monitoring of blood glucose (SMBG), improves diabetic outcomes (still controversial for Type 2 diabetes)
  - In hospital: Facilitates glycemic control, need rapid decisions to titer insulin and prevent hospital-acquired hypoglycemia (2-fold increase in chance of death in hospital)

Capillary glucose measurement

- Capillary vs. arterial/venous glucose
- Two primary limitations capillary glucose measurement
  - Glucose lag: 20-50 mg/dL difference between venous and capillary glucose in 30-60 minutes after meal (effect blunted in diabetics and critically ill)
  - Physiologic differences between capillary and venous glucose when tissue perfusion impaired (extended lag)
- Impact of BP, edema and shock, tissue perfusion
  - Blood pressure: Shock (systolic BP less than 80 mm Hg) associated with falsely decreased or increased capillary glucose measurement

Capillary glucose measurement

- Accuracy of capillary WB at low and high glucose
  - Khan et al Arch Pathol Lab Med 2006;130:1527-32
  - Kanji et al Crit Care Med 2005;33:2778-85
- Only 1 of 3 FDA-approved glucose meters (healthcare use) approved for capillary sampling in all hospitalized patients (including critically ill patients)
- Did not meet CLSI POCT12-A3 or FDA defined requirements for accuracy using capillary blood, but still approved as benefits of rapid turnaround time thought to exceed dangers of inaccuracies in capillary glucose measurement

POC INR measurement
Why monitor warfarin

- Narrow therapeutic window
- Variability in patient response
  - Genetics
  - Co-morbidities
- Drug and diet interactions
- Time delay (~1 day) between dosing and ability to measure response

POC INR measurement
Why monitor warfarin

- Target INR 2.0 – 3.0
  - INR 4.5: 2-3 fold increase in risk of bleeding
  - INR 5.5: 5 fold increase
  - INR >6.0: 8-10 fold increase
- Risk of repeat thromboembolism as INR decreases below 2.0 increases rapidly
- Goal is to prevent venous thromboembolism while minimizing the risk of hemorrhage
  - --Setting the right target range
  - --Getting to the right target quickly
  - --Staying in the therapeutic range as much as possible

POC INR testing
Why monitor warfarin

- Times of increased risk with sub- or supra-therapeutic levels
  - Initiation of therapy
  - Changes in medications and/or diet
  - Illness, hospitalization
  - Transitions of care
    - Hospital discharge
    - Provider change

POC INR testing
Why monitor warfarin

- Success and safety of therapy contingent upon
  - Patient knowledge & compliance
  - Education opportunities during therapy/measurement
  - Provider knowledge, experience & diligence
  - Need to follow up after INR result for treatment recommendation?
  - Systems of care delivery
  - How good is system at ensuring INR measurment at correct time/intervals, recommendations for treatment reach patient, patient understands recommendations

  - Time in therapeutic range, incidence of both bleeding and thrombosis, both improved by coagulation clinic or home capillary INR monitoring

POC INR testing

Is it accurate?

- Venous blood PT/INR testing
  - Gold standard warfarin monitoring
  - Venous blood in citrate anticoagulant, add back Ca and thromboplastin (phospholipids) to activate extrinsic clotting pathway, time (in seconds) for blood to clot is prothrombin time (PT) converted to INR
- Capillary INR monitoring
  - Capillary fingerstick sample applied to strip (capillary blood will contain some cell fragments (phospholipid), calcium not chelated with EDTA so available to initiate clotting
  - Strip contains thromboplastin (same lipid substance used in lab PT/INR), as blood clots electrochemical current changes used to measure clotting time in seconds (PT), convert to INR

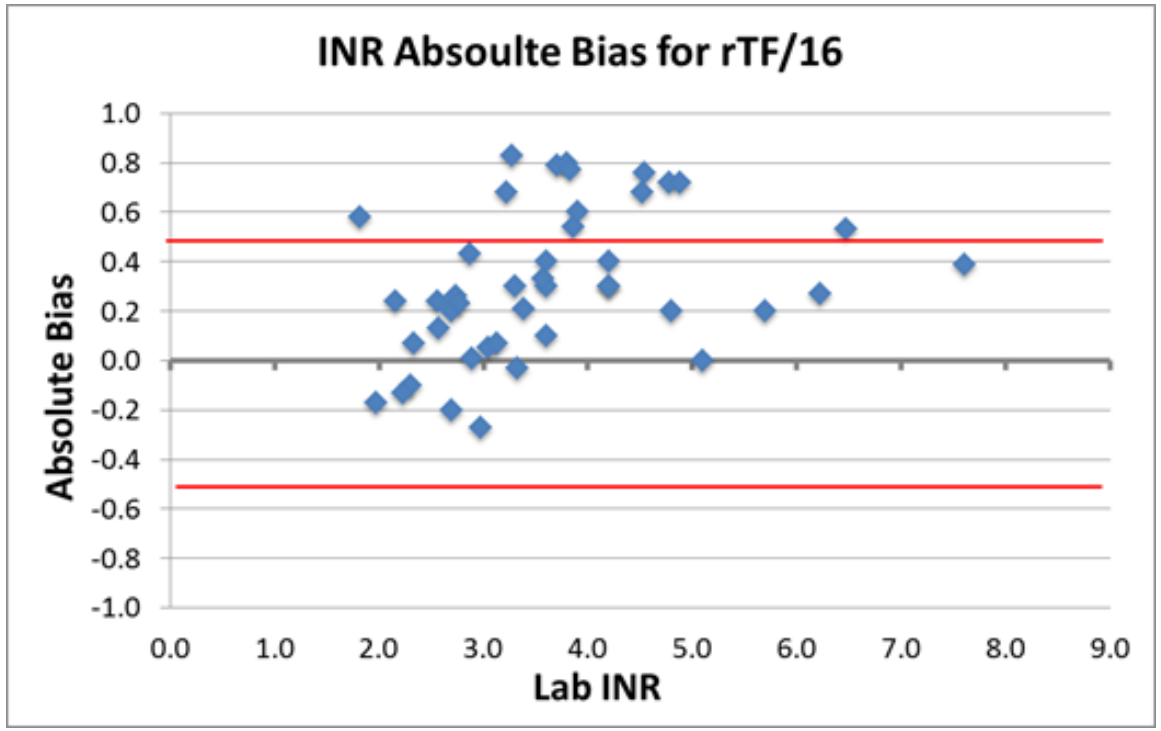
POC INR testing
Is it accurate?

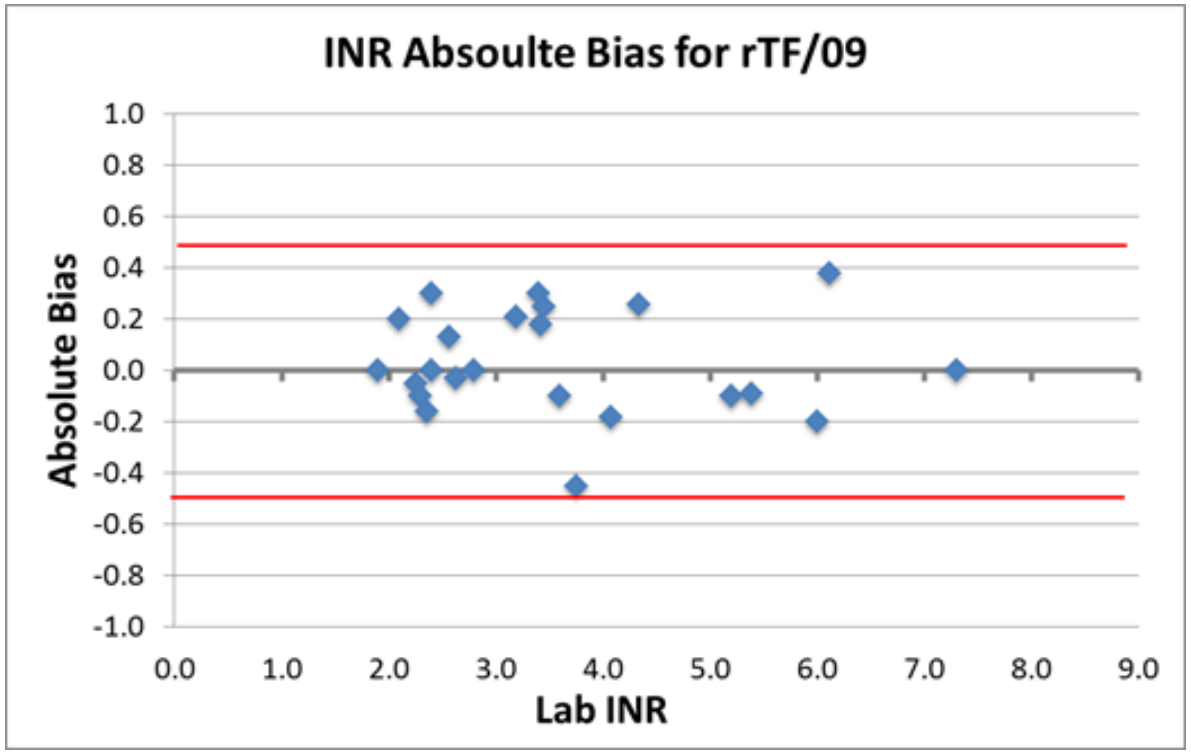
- Accuracy of POC INR relative to laboratory plasma INR
  - Multiple studies show 90% or more POC INR results are within ± 0.5 INR units of lab plasma INR, 5-10% of results will differ from lab plasma INR by ≥ 1.0 INR unit
  - Need to “pair” POC and lab methods for consistent results within healthcare system (no truth in coag)
  - Warfarin dosing discrepancies common
  - Favorable outcome associated with POC INR measurement means fewer patients harmed by inaccurate POC INR compared to number that might have harm due to insufficient monitoring without POC
  - Only FDA-approved for patients stably anticoagulated with warfarin, mostly adults

POC INR testing

Is it accurate?

- POC INR (and most other POC tests) have greater variability over time due to lot to lot drift and change in calibration to reference methods





Capillary sampling in adults: Other use cases

- Hemoglobin A1C (monitor glycemic control per guidelines in diabetic patients)
- Lipid testing (perhaps, accuracy still an issue with capillary collection and methods)
- Sexually transmitted disease (HIV screening particularly, although oral fluid methods also available)

Summary

- Capillary heelstick samples collected frequently in infants
  - Arterialized blood gas, basic chemistries other than K and direct bilirubin, CBCs
  - In children not used frequently at Mayo, fingerstick venous blood gas done rarely
- Capillary sampling in adults
  - Primarily limited to use cases requiring rapid action after testing, or where evidence better outcomes from POC testing
    - Glucose, INR, hemoglobin A1C, possibly lipids or STDs

QUESTIONS & DISCUSSION

Next Upcoming Webinar

Quality Metrics

Michele Legried

November 18, 2020

11am-12pm CT

