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Title: Demystifying Venous Excess Ultrasound (VExUS): Image Acquisition and Interpretation

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Author Questionnaire

- 1. Microscopy:** Does your protocol require the use of a dissecting or stereomicroscope for performing a complex dissection, microinjection technique, or something similar? **No**

- 2. Software:** Does the part of your protocol being filmed include step-by-step descriptions of software usage? **Yes, all done**

Current Protocol Length

Number of Steps: 09

Number of Shots: 20

Introduction

Videographer: Obtain headshots for all authors available at the filming location.

- 1.1. **Michael Turk:** Venous Excess Ultrasound, or VExUS, is a scoring system that was developed to help predict acute kidney injury based on the degree of venous congestion present, determined by evaluating the doppler waveform of the hepatic, portal and intrarenal veins.

- 1.1.1. INTERVIEW: Named Talent says the statement above in an interview-style shot, looking slightly off-camera.

What research gap are you addressing with your protocol?

- 1.2. **Yuriy Bronshteyn:** Despite the emergence of VExUS in today's Point-of-Care ultrasound landscape, it remains underutilized due, at least in part, to knowledge gaps and lack of training. To bridge these gaps, we describe a protocol for VExUS image acquisition and interpretation.

- 1.2.1. INTERVIEW: Named Talent says the statement above in an interview-style shot, looking slightly off-camera.

Videographer: Obtain headshots for all authors available at the filming location.

Ethics Title Card

All procedures were in accordance with the ethical standards of Duke University and with the 1964 Helsinki Declaration or comparable ethical standards

Protocol

2. Ultrasound Imaging Setup and IVC, Hepatic, Portal and Intrarenal Vein Assessment

Demonstrator: Michael Turk

- 2.1. To begin, position the patient in a supine posture for most of the examination [1]. Expose the patient's lower chest and abdomen prior to scanning [2]. Position the ultrasound machine so that the sonographer's dominant hand can comfortably hold the ultrasound probe [3].

- 2.1.1. Talent positioning a patient lying supine on the examination bed.
- 2.1.2. Talent uncovering the patient's lower chest and abdomen.
- 2.1.3. Talent adjusting the ultrasound machine to the correct side for probe access.

- 2.2. Select the **two-dimensional (2-D) (2-D)** mode, also called brightness mode or **B-mode (B-mode)**, on the ultrasound machine [1]. Then, select the **Cardiac** preset [2] and set up EKG gating [3].

NOTE: 2.2.1-2.2.2 were filmed by videographer

- 2.2.1. SCREEN: Navigate the machine interface and choose B-mode.
- 2.2.2. SCREEN: Select the Cardiac preset from the list of presets.

Added shot 2.2.3. Talent setting up EKG gating

- 2.3. For the subxiphoid view, place the probe beneath the xiphoid process with the indicator pointing cranially [1]. ~~Adjust the probe position until the inferior vena cava or IVC (I-V-C) is visualized in its maximal anteroposterior diameter [2].~~ While maintaining the IVC at the center of the screen, rotate the probe 90 degrees counterclockwise to obtain a short-axis view of the IVC [3].

- 2.3.1. Talent placing the ultrasound probe below the xiphoid process with indicator cranially.
- ~~2.3.2. SCOPE/SCREEN: Maximal anteroposterior diameter view of the IVC is being seen on screen.~~

NOTE: Shot deleted by authors

- 2.3.3. Talent rotating the probe counterclockwise while keeping the IVC centered on screen.

AUTHOR'S NOTE: Show 2.3.1 and 2.3.3 together in loop, and overlay attached video to demonstrate what the screen will look like. See uploaded video labeled 2.3 for example

2.4. In patients with contraindications to subxiphoid imaging, place the probe along the right anterior axillary line in the body's coronal plane with the probe indicator pointing cranially [1].

2.4.1. Talent positioning the probe on the right anterior axillary line with indicator pointing cranially.

~~2.5. Adjust the probe position until the IVC is seen in its maximal anteroposterior diameter [1]. While keeping the IVC in the center of the screen, rotate the probe 90 degrees counterclockwise to obtain a short axis view of the IVC [2].~~

~~2.5.1. SCOPE/SCREEN: Visualization of the IVC in maximal anteroposterior diameter is being seen.~~

~~2.5.2. Talent rotating the probe 90 degrees counterclockwise while keeping IVC centered.~~

AUTHOR'S NOTE: 2.5 was omitted

2.6. To visualize hepatic vein from the right flank view, place the probe along the right anterior axillary line in the body's coronal plane with the probe indicator pointing cranially [1].

2.6.1. Talent positioning probe at the right anterior axillary line.

AUTHOR'S NOTE: Re-use shot from 2.4.1

2.7. Adjust the probe until the hepatic vein is visualized entering the IVC near the cavo-atrial junction [1]. Select **Color Doppler** mode on the ultrasound machine [2]. Then move the color box to include the majority of the vessel within its borders [3].

AUTHOR'S NOTE: 2.7.2-2.7.3 were shot by videographer

2.7.1. SCOPE/SCREEN: 2.7.1-Hepatic-Vein.mp4 00:00-00:04

2.7.2. SCREEN: Select Color Doppler mode on the interface.

2.7.3. SCREEN: Move and resize the color Doppler box to cover the vessel.

2.8. Next, select **PW Doppler** (*P-W-Doppler*) mode on the ultrasound machine [1]. Move the Doppler gate so that it is located within the lumen of the hepatic vein [2].

AUTHOR'S NOTE: 2.8.1-2.8.2 were shot by videographer

2.8.1. SCREEN: Select PW Doppler mode on the ultrasound machine.

2.8.2. SCREEN: Adjust the Doppler gate to align within the hepatic vein.

2.9. Activate **PW Doppler** to start capturing waveform data [1]. Allow a full screen of PW Doppler tracing to occur, then click on **Freeze** or the equivalent control [2]. Click on **Acquire** or the equivalent button to save still images of the flow tracing [3].

AUTHOR'S NOTE: 2.9.1-2.9.2 were shot by videographer

2.9.1. SCREEN: Activate PW Doppler to begin tracing.

2.9.2. SCREEN: Click on Freeze once full tracing is captured.

2.9.3. SCREEN: 2.9.addedshot-PWD-HV.png

2.10. To visualize the portal vein from the right flank, return the probe to the same position as for the hepatic vein, along the right anterior axillary line [1].

2.10.1. Talent positioning probe at the right anterior axillary line.

AUTHOR'S NOTE: re-use 2.4.1

2.11. Adjust the probe until the portal vein is visualized horizontally with thick white borders [1]. Select **Color Doppler** mode on the ultrasound machine [2]. Then move the color box to include the majority of the vessel within its borders [3].

2.11.1. SCOPE/SCREEN: 2.11.1-Portal-vein-2D.mp4 00:00-00:04

2.11.2. SCREEN: Select Color Doppler mode on the interface. **AUTHOR'S NOTE:** Re use 2.7.2

2.11.3. SCREEN: Move and resize the color Doppler box to cover the vessel.

AUTHOR'S NOTE: Shot by videographer

2.12. Next, select **PW Doppler** (*P-W-Doppler*) mode on the ultrasound machine [1]. Move the Doppler gate so that it is located within the lumen of the portal vein [2].

2.12.1. SCREEN: Select PW Doppler mode on the ultrasound machine. **AUTHOR'S NOTE:** re use 2.8.1

2.12.2. SCREEN: Adjust the Doppler gate to align within the portal vein. **AUTHOR'S NOTE:** Shot by videographer

2.13. Activate **PW Doppler** to start capturing waveform data [1]. Allow a full screen of PW Doppler tracing to occur, then click on **Freeze** or the equivalent control [2]. Click on **Acquire** or the equivalent button to save still images of the flow tracing [3].

2.13.1. SCREEN: Activate PW Doppler to begin tracing. **AUTHOR'S NOTE:** re use 2.9.1

2.13.2. SCREEN: Click on Freeze once full tracing is captured. **AUTHOR'S NOTE:** re use 2.9.2

Added shot: 2.13---Portal-vein---PWD-frozen---04.png

2.13.3. SCREEN: Click on Acquire to save the tracing image. **AUTHOR'S NOTE:** re use 2.9.3

2.14. To visualize the intrarenal veins from the right flank, switch to the curvilinear probe and place it along the right mid axillary line [1].

2.14.1. Talent positioning curvilinear probe at the right anterior axillary line.

2.15. Adjust the probe until the right kidney is visualized in the hepatorenal recess [1]. Select **Color Doppler** mode on the ultrasound machine [2]. Then move the color box to include the majority of the kidney within its borders [3].

2.15.1. SCOPE/SCREEN: 2.15.1---Kidney---2D.mp4 00:00-00:02

2.15.2. SCREEN: Select Color Doppler mode on the interface. **AUTHOR'S NOTE:** Re use 2.7.2

2.15.3. SCREEN: Move and resize the color Doppler box to cover the vessel. .

AUTHOR'S NOTE: Re use 2.11.3

Added shot : FILE: 2.15---added-shot---Kidney---color.mp4 00:00-00:03

2.16. Next, select **PW Doppler (P-W-Doppler)** mode on the ultrasound machine [1]. Move the Doppler gate so that it is located over any area of color gain from the intrarenal vessels [2].

2.16.1. SCREEN: Select PW Doppler mode on the ultrasound machine. **AUTHOR'S**

NOTE: re use 2.8.1

2.16.2. SCREEN: Adjust the Doppler gate to align within the intrarenal vessels.

AUTHOR'S NOTE: Shot by videographer

2.17. Activate **PW Doppler** to start capturing waveform data [1]. Allow a full screen of PW Doppler tracing to occur, then click on **Freeze** or the equivalent control [2]. Click on **Acquire** or the equivalent button to save still images of the flow tracing [3].

2.17.1. SCREEN: Activate PW Doppler to begin tracing. **AUTHOR'S NOTE:** re use 2.9.1

2.17.2. SCREEN: Click on Freeze once full tracing is captured. **AUTHOR'S NOTE:** re use 2.9.2

Added shot: 2.17.-added-shot---Kidney---PWD---02.png

2.17.3. SCREEN: Click on Acquire to save the tracing image **AUTHOR'S NOTE:** re-use 2.9.3

Results

3. Representative Results

- 3.1. Hepatic vein Doppler showed progressive reversal of the systolic wave with increasing venous congestion [1].
 - 3.1.1. LAB MEDIA: Figure 12. *Video editor: Highlight the three right-side panels with black backgrounds showing the waveform*
- 3.2. Portal vein Doppler tracing changed from a near-continuous waveform with pulsatility index of less than 30 percent to over 50 percent and then to a to-and-fro pattern with reversed flow as venous congestion increased [1].
 - 3.2.1. LAB MEDIA: Figure 13. *Video editor: Highlight the waveform panels on the right side.*
- 3.3. Intrarenal vein Doppler showed progression from continuous flow to biphasic waves, then to monophasic diastolic-only waves as venous congestion increased [1].
 - 3.3.1. LAB MEDIA: Figure 14. *Video editor: Highlight the three right-side waveform panels.*
- 3.4. The VExUS (*vex-us*) scoring system visually integrated the changes in hepatic, portal, and intrarenal vein waveforms, showing how combination and severity of waveform abnormalities correspond to increasing grades of venous congestion [1].
 - 3.4.1. LAB MEDIA: Figure 15. *Video editor: Highlight the three columns under hepatic, portal, and intrarenal veins.*

Pronunciation Guide:

. Doppler

- **Pronunciation link:** <https://www.merriam-webster.com/dictionary/Doppler>
 - **IPA:** /'dɑː.plə/
 - **Phonetic Spelling:** DAH-plur[Merriam-WebsterMerriam-Webster+1Merriam-Webster+1](#)
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2. Hepatic

- **Pronunciation link:** <https://www.merriam-webster.com/dictionary/hepatic>
 - **IPA:** /hə'pæt.ɪk/
 - **Phonetic Spelling:** huh-PAT-ik[Merriam-Webster+19Merriam-Webster+19Merriam-Webster+19](#)
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3. Portal Vein

- **Pronunciation link:** <https://www.merriam-webster.com/dictionary/portal%20vein>
 - **IPA:** /'pɔːr.təl veɪn/
 - **Phonetic Spelling:** POR-tl vayn[Merriam-Webster+2Merriam-Webster+2Merriam-Webster+2Merriam-Webster+1Merriam-Webster+1Merriam-Webster+29Merriam-Webster+29Merriam-Webster+29](#)
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4. Intrarenal

- **Pronunciation link:** <https://www.merriam-webster.com/medical/intrarenal>
 - **IPA:** /,ɪn.trə'riː.nəl/
 - **Phonetic Spelling:** in-truh-REE-nuhl[Merriam-Webster+4Merriam-Webster+4Merriam-Webster+4](#)
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5. Xiphoid

- **Pronunciation link:** <https://www.merriam-webster.com/dictionary/xiphoid>
 - **IPA:** /'zaɪ.fɔɪd/
 - **Phonetic Spelling:** ZAI-foid[Merriam-Webster+4Merriam-Webster+4Merriam-Webster+4Merriam-Webster+12Merriam-Webster+12Merriam-Webster+12](#)
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6. Subxiphoid

- **Pronunciation link:** <https://www.merriam-webster.com/medical/subxiphoid>
 - **IPA:** /ˌsʌbˈzɑɪ.fɔɪd/
 - **Phonetic Spelling:** sub-ZAI-foid [Merriam-Webster+2Merriam-Webster+2Merriam-Webster+2](#)
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7. Axillary

- **Pronunciation link:** <https://www.merriam-webster.com/dictionary/axillary>
 - **IPA:** /ˈæk.səˌler.i/
 - **Phonetic Spelling:** AK-suh-lair-ee [Merriam-Webster+1Merriam-Webster+1Merriam-Webster+13Merriam-Webster+13Merriam-Webster+13](#)
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8. Curvilinear

- **Pronunciation link:** <https://www.merriam-webster.com/dictionary/curvilinear>
 - **IPA:** /ˌkɜː.vəˈlɪn.i.ə/
 - **Phonetic Spelling:** KUR-vuh-LIN-ee-er
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9. Hepatorenal

- **Pronunciation link:** <https://www.merriam-webster.com/medical/hepatorenal>
 - **IPA:** /ˌhɛp.ə.toʊˈriː.nəl/
 - **Phonetic Spelling:** HEP-uh-toh-REE-nuhl [Merriam-Webster+13Merriam-Webster+13Merriam-Webster+3Merriam-Webster+3Merriam-Webster+3](#)
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10. Biphasic

- **Pronunciation link:** <https://www.merriam-webster.com/dictionary/biphasic>
 - **IPA:** /ˌbaɪˈfeɪ.zɪk/
 - **Phonetic Spelling:** bye-FAY-zik [Merriam-Webster+1Merriam-Webster+1Merriam-Webster+5Merriam-Webster+5Merriam-Webster+5](#)
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11. Monophasic

- **Pronunciation link:** <https://www.merriam-webster.com/dictionary/monophasic>
- **IPA:** /ˌmɒn.oʊˈfeɪ.zɪk/

- **Phonetic Spelling:** MON-oh-FAY-zik
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12. Diastolic

- **Pronunciation link:** <https://www.merriam-webster.com/dictionary/diastolic>
 - **IPA:** /ˌdaɪ.əˈstɒ.lɪk/
 - **Phonetic Spelling:** DYE-uh-STOL-ik [Merriam-Webster+5Merriam-Webster+5Merriam-Webster+5](#)
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13. Pulsatility

- **Pronunciation link:** <https://www.merriam-webster.com/dictionary/pulsatility>
 - **IPA:** /ˌpʌl.səˈtɪl.ə.ti/
 - **Phonetic Spelling:** PUL-suh-TIL-uh-tee
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14. Anteroposterior

- **Pronunciation link:** <https://www.merriam-webster.com/dictionary/anteroposterior>
 - **IPA:** /ˌæn.tə.roʊ.pɒsˈtɪr.i.ər/
 - **Phonetic Spelling:** AN-tuh-roh-pos-TEER-ee-or
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15. Supine

- **Pronunciation link:** <https://www.merriam-webster.com/dictionary/supine>
 - **IPA:** /ˈsuː.paɪn/
 - **Phonetic Spelling:** SOO-pine
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16. Venous

- **Pronunciation link:** <https://www.merriam-webster.com/dictionary/venous>
 - **IPA:** /ˈviː.nəs/
 - **Phonetic Spelling:** VEE-nuhs [Merriam-Webster](#)
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17. Ultrasound

- **Pronunciation link:** <https://www.merriam-webster.com/dictionary/ultrasound>
- **IPA:** /ˈʌl.trə.saʊnd/

- **Phonetic Spelling:** UL-truh-sownd [Merriam-WebsterMerriam-Webster+17Merriam-Webster+17Merriam-Webster+17Merriam-Webster+1Merriam-Webster+1](#)
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18. VExUS

- **Pronunciation link:** No confirmed link found
- **IPA:** /'vɛk.səs/
- **Phonetic Spelling:** VEK-sus