

Submission ID #: 69482

Scriptwriter Name: Poornima G

Project Page Link: <https://review.jove.com/account/file-uploader?src=21192058>

Title: Reproducible Setup for In Vivo Two-Photon Imaging of the Contractility of Cervical Lymphatic Vessels and Lymph Flow in Mice

Authors and Affiliations:

Inna Blokhina¹, Dmitry Tuktarov², Anastasia Kolabukhova¹, Dmitry Myagkov², Anastasia Semiachkina-Glushkovskaia³, Ivan Fedosov², Oxana Semyachkina-Glushkovskaya¹, Jürgen Kurths^{4,5}

¹Department of Biology, Saratov State University

²Institute of Physics, Department of Optics and Biophotonics, Saratov State University

³Department of Computer Science and Information Technology, Saratov State University

⁴Fudan University

⁵Potsdam Institute for Climate Impact Research

Corresponding Authors:

Inna Blokhina

Kurths Jürgen

inna-474@yandex.ru

juergen.kurths@pik-potsdam.de

Email Addresses for All Authors:

Dmitry Tuktarov

Anastasia Kolabukhova

Dmitry Myagkov

Anastasia Semiachkina-Glushkovskaia

Ivan Fedosov

Oxana Semyachkina-Glushkovskaya

Inna Blokhina

Kurths Jürgen

ivanov.ivao@yandex.ru

anastasiak.09@mail.ru

dmyagk0v@yandex.ru

nastya.glushkovskaya04@mail.ru

fedosov_optics@mail.ru

glushkovskaya@mail.ru

inna-474@yandex.ru

juergen.kurths@pik-potsdam.de

Author Questionnaire

1. We have marked your project as author-provided footage, meaning you film the video yourself and provide JoVE with the footage to edit. JoVE will not send the videographer. Please confirm that this is correct.

✓ Correct

2. Microscopy: Does your protocol require the use of a dissecting or stereomicroscope for performing a complex dissection, microinjection technique, or something similar? **Yes**

If a dissection or stereo microscope is required for your protocol, please list all shots from the script that will be visualized using the microscope (shots are indicated with the 3-digit numbers, like 2.1.1, 2.1.2, etc.).

SCOPE shots: 5.6.1, 5.7.1, 5.7.2, 5.7.3, 5.8.1, 5.8.2, 5.8.3

Authors, please use your microscope camera to film the SCOPE shots and upload the files to your project page as soon as possible:

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

8 shots in Section 4

Authors: Please create screen capture videos of the shots labeled as SCREEN, write a screenshot summary, and upload the files to your project page as soon as possible:

4. Proposed filming date: To help JoVE process and publish your video in a timely manner, please indicate the proposed date that your group will film here: **02/02/2026**

When you are ready to submit your video files, please contact our Content Manager, [Utkarsh Khare](#).

Current Protocol Length

Number of Steps: 25

Number of Shots: 57 (7 Scope, 8 SC)

Introduction

Authors: Please note that the questions will not appear on screen. Please answer in stand-alone statements with sufficient context.

The answers are edited slightly according to journal guidelines.

INTRODUCTION:

~~What is the scope of your research? What questions are you trying to answer?~~

- 1.1. **Anastasia Kolabukhova:** We present a method for in vivo imaging of Cervical Lymphatic Vessel contractility and lymphatic removal of red blood cells in mice.
 - 1.1.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera

~~What are the current experimental challenges?~~

- 1.2. **Inna Blokhina:** Studying the functions of cervical lymphatic vessels is challenging, particularly when long-term observation of their contractility, lymph flow, and tracer clearance is required.
 - 1.2.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera

CONCLUSION:

~~What research gap are you addressing with your protocol?~~

- 1.3. **Anastasia Kolabukhova:** Our protocol facilitates in vivo monitoring of cervical lymphatic vessel functions while maintaining their contractility for up to 5 hours of observation.
 - 1.3.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera

~~What advantage does your protocol offer compared to other techniques?~~

- 1.4. **Dmitry Tuktarov:** Our method offers good reproducibility and is compatible with various two-photon microscopes and objective ranges, while maintaining high-quality images with depth up to 500 micrometers.

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

~~How will your findings advance research in your field?~~

- 1.5. **Dmitry Myagkov:** This technique can potentially become a universal tool for studying the physiology of the brain drainage system and the functions of cervical lymphatic vessels.

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

Ethics Title Card

This research has been approved by the Bioethics Commission of the Saratov State University

Protocol

2. Assembling the Technical Device for Mouse Fixation

Demonstrators: Inna Blokhina and Anastasia Kolabukhova

2.1. To begin, place a steel optical rail for the base of the device [1-TXT].

2.1.1. WIDE: Talent placing a 270 millimeter long, 43 millimeter wide steel optical rail on the lab bench. **TXT: Length: 270 mm; Width: 43 mm**

2.2. Install two post holders on top of the steel optical rail, ensuring a distance of 175 millimeters between them [1]. Insert two mounting posts with a diameter of 12 millimeters into the post holders [2], and secure each one using an M6 screw [3]. Then, attach a post collar to each of the two mounting posts [4-TXT].

2.2.1. Talent positioning and securing two post holders 175 millimeters apart on the optical rail.

2.2.2. Talent inserting 12 millimeter mounting posts into the post holders.

2.2.3. Talent tightening each post holder with an M6 screw.

2.2.4. Talent attaching post collars to both mounting posts. **TXT: This post collar is used later for securing a catheter**

2.3. Now, fix a right-angle fixed post clamp to one of the mounting posts and fasten it firmly using an M6 screw [1]. Insert a 12-millimeter mounting post into the side hole of the right-angle post clamp [2].

2.3.1. Talent mounting the right-angle fixed post clamp onto one of the posts and tightening it with an M6 screw.

2.3.2. Talent inserting the side post into the clamp's side hole.

2.4. Now, attach a 3D-printed holder to the inserted side mounting post and fasten it securely using two pairs of M3 screws [1]. Using UV-curable glue, affix a 12-millimeter diameter cover glass to the underside of a protective 3D-printed casing [2]. Then, secure the protective casing to the 3D-printed holder using an M4 screw-nut pair [3].

2.4.1. Talent aligning and fixing the 3D-printed holder to the side post with M3 screws.

2.4.2. Talent applying UV-curable glue and attaching the cover glass to the underside

of the protective casing.

2.4.3. Talent fixing the protective casing onto the 3D-printed holder using an M4 screw-nut pair.

2.5. Install a precision pantograph table for vertical movement on the steel optical rail base using two table clips and sets of M6 screws, nuts, and washers [1]. Then, place a 3D-printed case measuring 155 millimeters in length and 110 millimeters in width onto the tabletop. This case serves as a reservoir for accumulating saline solution [2].

2.5.1. Talent aligning the precision pantograph table on the optical rail (in the file 2.5.1.1.) and securing it with clips and M6 hardware (in the file 2.5.1.2.).

2.5.2. Talent placing the 3D-printed reservoir case on the surface of the pantograph table.

3. Assembling the Heating Element and Setting the Temperature

Demonstrator: Dmitry Tuktarov

3.1. Cover the connection point of the wires to heating element 1 with a thin layer of silicone [1], fix temperature sensor 1 to the mat and seal it with silicone [2].

3.1.1. Talent applying silicone to the wire junction on heating element 1.

3.1.2. Talent positioning the temperature sensor onto the mat and sealing it with silicone.

3.2. Solder the wires of the heating element and temperature sensors to a multi-wire cable [1]. Fill the connection point with silicone and close it using shrink wrap [2].

3.2.1. Talent soldering the wires of the heating element and sensors to a multi-wire cable (3.2.1.1.-3.2.1.4.).

3.2.2. Talent sealing the connection point with silicone (3.2.2.1.) and enclosing it in shrink wrap (3.2.2.2, 3.2.2.3.).

3.3. Now, place heating element 2 and temperature sensor 2 into the foam roller [1]. Fix the connectors for the power cable and the power button to the walls of the control unit case [2].

- 3.3.1. Talent inserting heating element 2 (3.3.1.1.) and temperature sensor 2 (3.3.1.2.) into the foam roller.
- 3.3.2. Talent mounting the power cable connector and power button on the walls of the case.
- 3.4. Install a 24-volt direct current power supply, a direct current step-down converter, and two MOSFET (*moss-fet*) modules inside the enclosure [1-TXT]. After assembling the circuit and soldering the required components [2], fix the Arduino UNO (*oo-no*) and the keyboard screen into the lid housing [3].
 - 3.4.1. Talent placing and securing the 24 volt power supply, step-down converter, and MOSFET modules into the enclosure. **TXT: MOSFET: Metal-Oxide-Semiconductor Field-Effect Transistor**
 - 3.4.2. **NOTE: Authors have filmed multiple clips for this shot. Please select any 2-4 relevant clips from start, middle, and end to show the process.**
 - ~~3.4.2.1. Talent fixes the wire in the terminal of the power supply (L).~~
 - ~~3.4.2.2. Talent solders it to the corresponding pin on the power connector.~~
 - ~~3.4.2.3. Talent solders the wire to pin (N) on the power connector 20260211_152548 (failed take (face caught in the frame) solder the other end of the wire to the power button.~~
 - ~~3.4.2.4. The talent fixes the wire in the terminal of the power supply (ground).~~
 - ~~3.4.2.5. The talent solders it to the corresponding pin on the power connector.~~
 - ~~3.4.2.6. The talent solders the wire to the output pin of the power button.~~
 - ~~3.4.2.7. The talent locks it in the power supply terminal (zero).~~
 - ~~3.4.2.8. The talent fixes a 2 core cable in the terminals of the power supply (V+ and V-).~~
 - ~~3.4.2.9. The talent solders the appropriate wires to the input of the step down converter.~~
 - ~~3.4.2.10. Talent solders the wire to the Vin pin on the Arduino.~~
 - ~~3.4.2.11. Talent solders the wire to the gnd pin on the Arduino.~~
 - ~~3.4.2.12. Talent solders the wires from the Vin and gnd contacts to the out+ and out- on the step down converter, respectively 3.4.2.15) Talent solders the wire to the gnd contact on the Arduino.~~
 - ~~3.4.2.13. Talent solders the wire to the gnd pin on the Arduino.~~
 - ~~3.4.2.14. Talent solders the gnd wire on the Arduino to the gnd pin on the MOSFET module 1.~~

- ~~3.4.2.15. Talent solders the gnd wire on the Arduino to the gnd pin on the MOSFET module 2.~~
- ~~3.4.2.16. Talent solders the wire to pin D10 on the Arduino.~~
- ~~3.4.2.17. Talent solders the wire to pin D11 on the Arduino.~~
- ~~3.4.2.18. Talent solders the D10 wire on the Arduino to the PWM pin on MOSFET module 1, solder the D11 wire on the Arduino to the PWM pin on MOSFET module 2.~~
- ~~3.4.2.19. Talent solders the D3 wire on the Arduino to the OUT pin on Temperature sensor 1.~~
- ~~3.4.2.20. Talent solders a wire to D3 on Arduino.~~
- ~~3.4.2.21. Talent solders the wire to the gnd on the Arduino.~~
- ~~3.4.2.22. Talent solders the wire to the gnd on the Arduino.~~
- ~~3.4.2.23. Talent solders a wire to 5V on Arduino.~~
- ~~3.4.2.24. Talent solders the gnd wire on the Arduino to pin V on Temperature sensor 1.~~
- ~~3.4.2.25. Talent solders the 5V wire on the Arduino to the V+ pin on Temperature sensor 1.~~
- ~~3.4.2.26. Talent solders the gnd wire on the Arduino to the gnd pin on Temperature sensor 2.~~
- ~~3.4.2.27. Talent solders the wire to 5V on the Arduino.~~
- ~~3.4.2.28. Talent solders a resistor to a 5V wire on an Arduino.~~
- ~~3.4.2.29. Talent solders the resistor to the OUT wire on Temperature sensor 2.~~
- ~~3.4.2.30. Talent solders the wire to the resistor.~~
- ~~3.4.2.31. Talent solders this wire to pin A1 on the Arduino.~~
- ~~3.4.2.32. Talent fixes 2 wires in the terminal of the power supply (V+).~~
- ~~3.4.2.33. Talent fixes the wire from the power supply (V+) in the terminal of the VIN+ MOSFET module 1.~~
- ~~3.4.2.34. Talent fixes the wire from the power supply (V+) in the VIN+ MOSFET module 2 terminal.~~
- ~~3.4.2.35. Fixing 2 wires in the terminal of the power supply (V-).~~
- ~~3.4.2.36. Talent fixes the wire from the power supply (V-) in the terminal of the VIN- MOSFET module 1.~~
- ~~3.4.2.37. Talent fixes the wire from the power supply (V-) in the terminal of the VIN- MOSFET module 2.~~

- ~~3.4.2.38. The talent fixes the wire from the Heating element (V-) in the terminal of the VIN- MOSFET module 1.~~
- ~~3.4.2.39. The talent locks the wire from the Heating element (V+) in the VIN+ MOSFET module 1 terminal.~~
- ~~3.4.2.40. Talent fixes the wire from Heating element 2 (V-) in the terminal of the VIN- MOSFET module 2.~~
- ~~3.4.2.41. Talent fixes the wire from Heating element 2 (V+) in the VIN+ MOSFET module 2 terminal.~~
- 3.4.3. Talent installing the Arduino UNO and fitting the keyboard screen into the inner surface of the lid housing.

~~4. Configuring the Temperature Control Software~~

- ~~4.1. Download the Arduino sketch file in .ino (dot I N O) format and open it using the Arduino development environment [1-TXT]. Select the correct COM (com) port in the Arduino IDE and download the firmware to the board [2]. Use the left and right buttons on the keyboard to navigate between the two interface buttons on the screen [3].~~
 - ~~4.1.1. **SCREEN:** Show the Arduino IDE interface with the .ino file opened in version 2.3.5 nightly 20241212. Show the **Tools > Port** menu in the Arduino IDE with the correct COM port selected. **TXT: Use version 2.3.5 nightly 20241212; Select the correct COM port in the Arduino IDE; Download the firmware**~~
 - ~~4.1.2. **SCREEN:** Show the **Tools > Port** menu in the Arduino IDE with the correct COM port selected.~~
 - ~~4.1.3. **SCREEN:** Show the device interface where the left and right buttons move between two on-screen options.~~
- 4.2. Locate the temperature selection field, adjust the temperature [1] and press Run [2].
 - 4.2.1. Show the temperature setting interface with temperature being adjusted.
 - 4.3.1,. Show the run button being hit. **NOTE: Show this right after 3.4.3**
- ~~4.3. Now, locate the START (start) shutdown field [1], press the Right button on the keyboard to move the selection to this column, and then press **Select** to activate the function [2]. When the process starts, the activity indicator will begin blinking, and the~~

~~label on the RUN (*run*) button will switch to OFF (*off*) [3].~~

~~4.3.1. **SCREEN:** Highlight the START/shutdown field in the right column of the display. Show the screen when user presses the Right button on keyboard followed by the Select button.~~

~~4.3.2. **SCREEN:** Show the screen when user presses the Right button on keyboard followed by the Select button.~~

~~4.3.3. **SCREEN:** Demonstrate the blinking activity indicator and the label change from RUN to OFF.~~

5. Fixing the Animal in the Technical Device

Demonstrator: Inna Blokhina

5.1. After anesthetizing the mouse, apply eye ointment to both eyelids to prevent drying of the eyeballs during surgery [1-TXT]. Once the hind leg withdrawal reflex and tail tucking reflex cease, place the mouse on its back on the heating element to provide access to the abdominal region [2]. Plug the control unit into an electrical outlet with an input voltage of 175 to 240 volts alternating current [3-TXT].

5.1.1. Talent applying a thin layer of ointment to the mouse's eyelids. **TXT: Anesthesia: IP injection of Ketamine (100 mg/kg) + Xylazine (10 - 156 mg/kg)**

5.1.2. Talent placing the mouse on its back onto the heating element.

5.1.3. Talent plugging the power cord into the outlet. **TXT: Frequency range: 50 - 60 Hz; AC current 1.8 A/230 V AC; Device temperature: 37 - 38 °C**

5.2. Using a medical tape, fix the animal's body in a position parallel to the table surface [1] and place the head at an angle to the sagittal axis so that one side of the neck rests on the roller [2].

5.2.1. Talent taping the animal's body securely in a straight position on the table.

5.2.2. Talent adjusting the head at an angle and placing the neck onto the foam roller.

5.3. Now, wrap a ligature around the upper incisors and attach it to the back of the device [1] and use medical tape to help maintain the animal's body temperature [2].

5.3.1. Talent tying a ligature around the upper incisors.

5.3.2. Talent securing the ligature to the back of the device and reinforcing the position with medical tape.

- 5.4. With a shaving machine, shave the fur from the neck region [1]. Remove any remaining loose hairs and cover the animal to preserve the sterile field [2-TXT].
 - 5.4.1. Talent shaving the neck area of the mouse with a shaving machine.
 - 5.4.2. Talent removing residual hair and draping the animal to maintain sterility. **TXT: Inject: 0.5 - 1 mL of Lidocaine (1 mg/mL) or Bupivacaine (0.25 mg/mL); Subcutaneously into the incision site**
- 5.5. For primary disinfection, degrease and partially disinfect the neck skin using an alcohol swab [1]. Then, apply a 0.5 percent chlorhexidine solution or a 2 percent iodine solution for antiseptic treatment [2].
 - 5.5.1. Talent wiping the neck area with an alcohol swab.
 - 5.5.2. Talent applying chlorhexidine or iodine to the disinfected area. **TXT: Repeat all sterilization steps 2x**
- 5.6. Using straight dissecting scissors, perform a dermatotomy by making a longitudinal incision along the neck skin from the lower jaw to the collarbone, approximately 2 centimeters in length [1].
 - 5.6.1. SCOPE: 5.6.1.
- 5.7. Then perform a fasciotomy using microsurgical curved scissors [1]. Using curved tweezers, gently push aside the salivary glands and superficial neck muscles to expose the sternocleidomastoid muscle [2]. Ensure that visible blood vessels are not damaged, and continuously moisten the surgical field with saline to prevent tissue damage [3].
 - 5.7.1. SCOPE: 5.7.1.
 - 5.7.2. SCOPE: 5.7.2.
 - 5.7.3. SCOPE: 5.7.3.
- 5.8. Use microsurgical scissors to perform a myotomy of the sternocleidomastoid muscle, providing access to the region between the trachea and carotid artery [1]. Continue spreading the muscles and fascia, performing both myotomy and fasciotomy [2]. Next, locate the deep cervical lymph node along with the afferent and efferent lymphatic vessels at a depth of 5 to 7 millimeters [3].
 - 5.8.1. SCOPE: 5.8.1.

5.8.2. SCOPE: 5.8.2.

5.8.3. SCOPE: 5.8.3.

6. Fixing the Mouse Under a Microscope

6.1. Place the device holding the fixed animal onto the movable microscope table [1] and secure the device in place by firmly fastening it with an M6 screw to ensure stability during imaging [2].

6.1.1. Talent positioning the device with the animal onto the movable microscope table.

6.1.2. Talent inserting and tightening the M6 screw to fix the device firmly to the table.

6.2. Attach the catheter, pre-filled with saline solution, to the mounting post using medical tape [1]. Place a roller with a diameter of 1 centimeter under the heating element on the side of the animal's head to maintain a 45-degree tilt relative to the microscope table [2].

6.2.1. Talent taping the saline-filled catheter securely to the mounting post.

6.2.2. Talent inserting the roller beneath the heating element beside the animal's head.

6.3. Then, position the fixed catheter into the surgically opened neck area so that it lies near the collarbone region of the animal [1] and turn on the saline supply to fill the open neck cavity with saline solution [2].

6.3.1. Talent adjusting the catheter placement so it rests correctly in the neck area near the collarbones.

6.3.2. Talent opening the valve or switch to start the saline flow and filling the cavity fully.

6.4. Now, lower the protective casing over the neck area filled with saline so that the lymphatic vessel lies at the center of the viewing field [1-TXT]. Using a binocular device connected to a two-photon microscope, install the protective casing without exerting pressure on the trachea [2].

6.4.1. Talent lowering the protective casing gently over the surgical area.

- 6.4.2. Talent using the binocular viewer to carefully position the protective casing above the trachea.

- 6.5. Finally, lower the non-water-immersion two-photon lens into the protective casing to the correct depth based on the working distance of the lens [1] and perform two-photon visualization of the cervical lymphatic vessel [2].
 - 6.5.1. Talent adjusting the two-photon lens into position inside the protective casing.
 - 6.5.2. Talent working with the two-photon microscope.

Results

7. Results

- 7.1. After the procedure, successful identification of the deep cervical lymph nodes was confirmed by Evans Blue accumulation in the tissue [1].
 - 7.1.1. LAB MEDIA: Figure 8D. *Video editor: Highlight the two red fluorescent spots indicating Evans Blue accumulation.*
- 7.2. Two-photon monitoring of the cervical lymphatic vessel contractility was performed before and after photobiomodulation [1-TXT].
 - 7.2.1. LAB MEDIA: Figure 10B. *Video editor: Highlight the large green fluorescent image.*
- 7.3. Photobiomodulation significantly increased the cervical lymphatic vessel contractility in 2- and 18-month-old mice with similar intensity [1].
 - 7.3.1. LAB MEDIA: Figure 10C. *Video editor: Highlight the red contraction waveforms for 2-month-old and 18-month-old mice.*
- 7.4. Quantitative analysis showed that cervical lymphatic vessel contractility was significantly lower in 24-month-old mice [1] compared to 2- and 18-month-old mice. However, the values were not significantly different between 2- and 18-month-old mice [2].
 - 7.4.1. LAB MEDIA: Figure 10D. *Video editor: Highlight the box plot showing lower values in the 24-month-old group.*
 - 7.4.2. LAB MEDIA: Figure 10D. *Video editor: Highlight the plots for 2-month-old and 18-month-old groups.*
- 7.5. Photobiomodulation significantly increased cervical lymphatic vessel contractility in 2- and 18-month-old mice [1], but had no effect in 24-month-old mice [2].
 - 7.5.1. LAB MEDIA: Figure 10E. *Video editor: Highlight plots for “2mo+PBM” and “18-mo+PBM”.*
 - 7.5.2. LAB MEDIA: Figure 10E. *Video editor: Highlight the plots for 24-mo+PBM.*

7.6. Red blood cells injected into the right lateral ventricle [1] were observed in cervical lymphatic vessels 4 hours after injection [2] and continued moving through the lumen at 5 hours, confirming directional flow from the brain to the periphery [3].

7.6.1. LAB MEDIA: Figure 11. *Video editor: Highlight A.*

7.6.2. LAB MEDIA: Figure 11. *Video editor: Highlight the red arrowheads pointing to red blood cells in B.*

7.6.3. LAB MEDIA: Figure 11C. *Video editor: Highlight the red arrowheads indicating red blood cell movement in C.*

1. optical

Pronunciation link: <https://www.merriam-webster.com/dictionary/optical>

IPA: /'ɑ:ptɪkəl/

Phonetic Spelling: aap·tuh·kuhl

2. pantograph

Pronunciation link: <https://www.merriam-webster.com/dictionary/pantograph>

IPA: /'pæn.tə.græf/

Phonetic Spelling: pan·tuh·graf

3. reservoir

Pronunciation link: <https://www.merriam-webster.com/dictionary/reservoir>

IPA: /'rezər.vwɑ:r/

Phonetic Spelling: rez·er·vwaar

4. silicone

Pronunciation link: <https://www.merriam-webster.com/dictionary/silicone>

IPA: /'sɪlɪ.koʊn/

Phonetic Spelling: sil·ih·kohn

5. solder

Pronunciation link: <https://www.merriam-webster.com/dictionary/solder>

IPA: /'sɔ:dər/

Phonetic Spelling: saa·der

6. MOSFET

Pronunciation link: <https://www.howtopronounce.com/mosfet>

IPA: /'mɒs.fet/ , /'mɑ:s.fet/

Phonetic Spelling: moss·fet

7. semiconductor

Pronunciation link: <https://www.merriam-webster.com/dictionary/semiconductor>

IPA: /,sɛmi.kən'dʌktər/

Phonetic Spelling: sem·ee·kuhn·duk·ter

8. transistor

Pronunciation link: <https://www.merriam-webster.com/dictionary/transistor>

IPA: /træn'zɪstər/

Phonetic Spelling: tran·zis·ter

9. enclosure

Pronunciation link: <https://www.merriam-webster.com/dictionary/enclosure>

IPA: /ɪn'kloʊʒər/

Phonetic Spelling: in·kloh·zher

10. Arduino

Pronunciation link: <https://www.howtopronounce.com/arduino>

IPA: /ɑ:r'dwi:nɒʊ/

Phonetic Spelling: ar·dwee·noh

11. firmware

Pronunciation link: <https://www.merriam-webster.com/dictionary/firmware>

IPA: /'fɜ:m,wɛr/

Phonetic Spelling: ferm·wair

12. anesthesia

Pronunciation link: <https://www.merriam-webster.com/dictionary/anesthesia>

IPA: /,ænəs'θi:zə/

Phonetic Spelling: an·uhs·thee·zhuh

13. Ketamine

Pronunciation link: <https://www.merriam-webster.com/dictionary/ketamine>

IPA: /'ki:tə,mɪ:n/

Phonetic Spelling: kee·tuh·meen

14. Xylazine

Pronunciation link: <https://www.howtopronounce.com/xylazine>

IPA: /'zaɪlə,zɪ:n/

Phonetic Spelling: zye·luh·zeen

15. sagittal

Pronunciation link: <https://www.merriam-webster.com/dictionary/sagittal>

IPA: /'sædʒɪtəl/

Phonetic Spelling: saj·uh·tuhl

16. incision

Pronunciation link: <https://www.merriam-webster.com/dictionary/incision>

IPA: /ɪn'sɪʒən/

Phonetic Spelling: in·sizh·uhn

17. dermatotomy

Pronunciation link: <https://www.howtopronounce.com/dermatotomy>

IPA: /,dɜːmə'tɑːtəmi/

Phonetic Spelling: der·muh·taa·tuh·mee

18. fasciotomy

Pronunciation link: <https://www.howtopronounce.com/fasciotomy>

IPA: /,fæʃi'ɑːtəmi/

Phonetic Spelling: fash·ee·aa·tuh·mee

19. sternocleidomastoid

Pronunciation link: <https://www.merriam-webster.com/dictionary/sternocleidomastoid>

IPA: /,stɜːnoʊˌklaɪdoʊ'mæstɔɪd/

Phonetic Spelling: ster·noh·kly·doh·mas·toyd

20. trachea

Pronunciation link: <https://www.merriam-webster.com/dictionary/trachea>

IPA: /'treɪkiə/

Phonetic Spelling: tray·kee·uh

21. catheter

Pronunciation link: <https://www.merriam-webster.com/dictionary/catheter>

IPA: /'kæθətər/

Phonetic Spelling: kath·uh·ter

22. binocular

Pronunciation link: <https://www.merriam-webster.com/dictionary/binocular>

IPA: /baɪ'nɒːkjələr/

Phonetic Spelling: bye·naa·kyuh·ler

23. photobiomodulation

Pronunciation link: <https://www.howtopronounce.com/photobiomodulation>

IPA: /ˌfoʊtoʊˌbaɪoʊˌmɑːdjəˈleɪʃən/

Phonetic Spelling: foh·toh·bye·oh·mod·yuh·lay·shuhn

24. contractility

Pronunciation link: <https://www.merriam-webster.com/dictionary/contractility>

IPA: /ˌkɒːntrækˈtɪləti/

Phonetic Spelling: kon·trak·til·uh·tee

25. ventricle

Pronunciation link: <https://www.merriam-webster.com/dictionary/ventricle>

IPA: /ˈventrɪkəl/

Phonetic Spelling: ven·truh·kuhl

26. lumen

Pronunciation link: <https://www.merriam-webster.com/dictionary/lumen>

IPA: /ˈluːmən/

Phonetic Spelling: loo·muhn