MRI を用いた動物のイメージング（講義）
Introduction to magnetic resonance imaging (MRI) in animals (Lecture in Japanese)

山田 篤史（創発的研究センター・先端医療研究開発部門）
Atsushi Yamada (Advanced Medical Research and Development Division, Medical Innovation Research Center)

本講義では，Magnetic Resonance Imaging（MRI）の撮影原理を説明する．そして，本学の動物実験用 3T MRI の操作方法や撮影シーケンスの種類，それによる撮影画像の違いを具体的に説明する．また，医用画像処理ソフトでの MRI 画像の取り扱いについて説明する．
MRI 画像の応用例として，術前・術中 MRI 画像を用いた治療法の説明や，画像誘導手術などを紹介する．

This lecture will teach us about magnetic resonance imaging (MRI) and how it works. We'll first explore the specific operations involved in using the 3-tesla MRI scanner for animal studies in this university, various scan sequences, and image differences by their scan sequences. Then, scanned image operations using medical image processing software are explained. Furthermore, medical applications using MRI images are introduced, including preoperative and intraoperative imaging and image-guided surgeries.

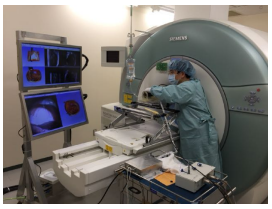
Introduction to Magnetic Resonance Imaging (MRI) in animals

Atsushi Yamada, PhD
Specially Appointed Associate Professor
Advanced Medical Research and Development Division
Medical Innovation Research Center

Sep 13/2024

Topics

- **MRI in animal experiments**
- **Post-processing software**
- **Research for image-guided therapies**



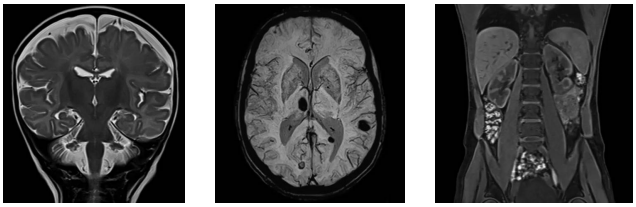
#1 Magnetic resonance imaging (MRI)

MRI scanners in SUMS

3 T MRI scanner (Verio dot, SIEMENS Healthineers)

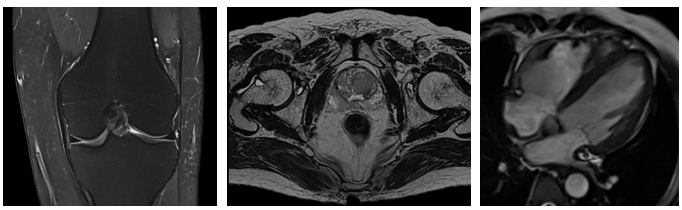
4.7 T MRI scanner (BioSpec 47/40 USR, Bruker)
https://www.bruker.com/ja/products-and-solutions/preclinical-imaging/mri/biospec/biospec-47-40.html

MRI images



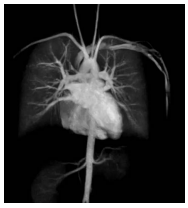
Verio dot 3T, Siemens Healthineers
https://www.siemens-healthineers.com/en-us/magnetic-resonance-imaging/3t-mri-scanner/magnetom-verio

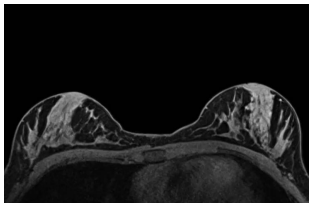
MRI images



Verio dot 3T, Siemens Healthineers
https://www.siemens-healthineers.com/en-us/magnetic-resonance-imaging/3t-mri-scanner/magnetom-verio

MRI images



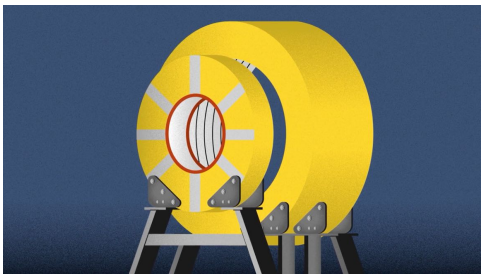


Verio dot 3T, Siemens Healthineers
https://www.siemens-healthineers.com/en-us/magnetic-resonance-imaging/3t-mri-scanner/magnetom-verio

Imaging mechanism

Dr. Paulien Moyaert, How does an MRI works? | MRI basics expained | Animation
https://www.youtube.com/watch?v=FvOezMIL9BU

Imaging mechanism



Science Museum, How does an MRI machine work?
https://www.youtube.com/watch?v=nFkBhUYynUw

#2 MRI scanner

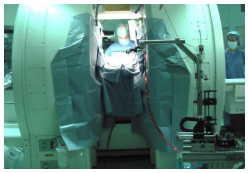
MRI scanner types

Verio dot 3T, Siemens Healthineers
Picture: 3T MRI room,
Shiga University of Medical Science

Closed bore type
3T

APERTO Lucent Plus, FUJIFILM Corp.
https://www.fujifilm.com/jp/ja/healthcare/mri-and-ct/permanent-magnet-open-mri-system/airis-vento-plus

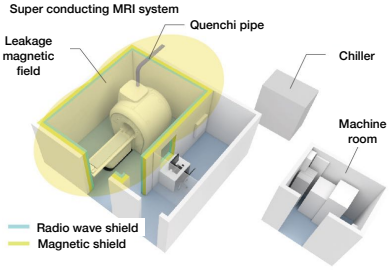
Horizontal open-bore type
0.4T



Signa SP/2, GE HealthCare
Picture: Interventional MRI room,
Shiga University of Medical Science Hospital

Vertical open-bore type
0.5T

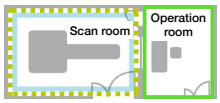
Scanner room



General structures for MRI scanner room
https://www.fujifilm.com/jp/ja/healthcare/mri-and-ct/permanent-magnet-open-mri-system/aperto-lucent-plus/cost-merit

Magnetic shield
Picture: 3T MRI room (at the time of under construction) in Shiga University of Medical Science

Magnetic field

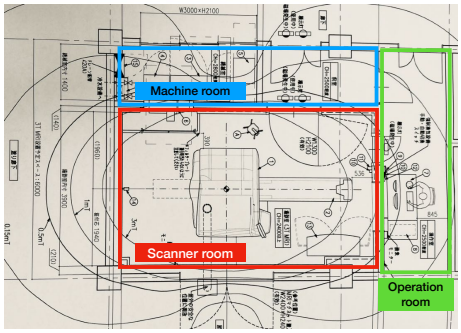


Radio wave shield

Magnetic shield

5 gauss line (0.5mT):
magnetic impact

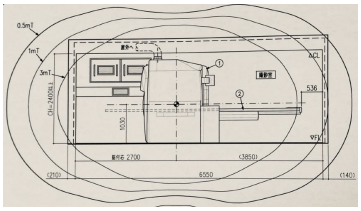
MRI keeps generating a magnetic field 365 days a year.



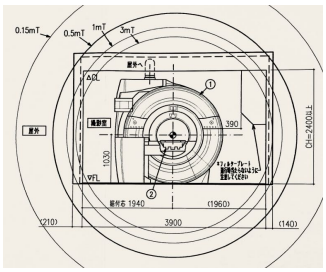
Room design: 3T MRI room in Shiga University of Medical Science

Magnetic field

5-gauss line (0.5mT)



Room design: 3T MRI room in Shiga University of Medical Science



Room design: 3T MRI room in Shiga University of Medical Science

Common dangerous accidents

Magnetic materials in scanner room

Playing with MRI before quenching 2019
https://www.youtube.com/watch?v=IF8CMrjQNN4&t=26s

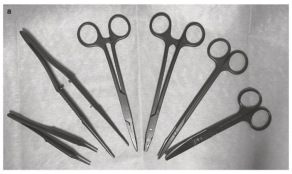
Dangers of MRI
https://www.youtube.com/watch?v=pIvlEf7JsKo&t=34s

MR compatible and incompatible

Incompatible
ID cards, bank cards, pens, scissors, staplers, keys, injectors, belts, watches, smartphones, PCs, ECUs, motors, cables, SUS medical tools, energy devices, etc.

Compatible
Ultrasonic motors and MRI-compatible devices and equipment made of nonmagnetic aluminum, titanium, copper, brass, resin, etc.

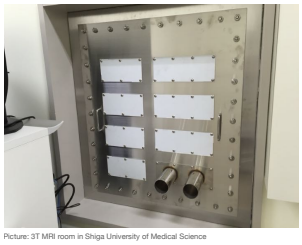
Yamada A, Tokuda J, Naka S, Murakami K, Tani T, Morikawa S (2020) Magnetic resonance and ultrasound image-guided navigation system using a needle manipulator. Med Phys 47(3):850–858. https://doi.org/10.1002/mp.13958



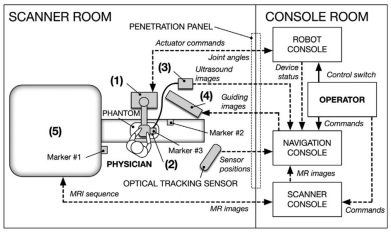
Mekata E., Yamada A., Shimagaki M., Kajiyama T., Tani T. (2021) Lightweight Carbon-Reinforced Resin Surgical Instruments. In: Takenoshita S., Yasuhara H. (eds) Surgery and Operating Room Innovation. Springer, Singapore. https://doi.org/10.1007/978-981-15-8979-9_1

Penetration panels

Cable access between the scanner room and console room



Picture: 3T MRI room in Shiga University of Medical Science



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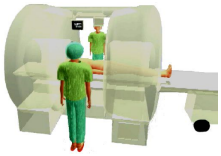
Points

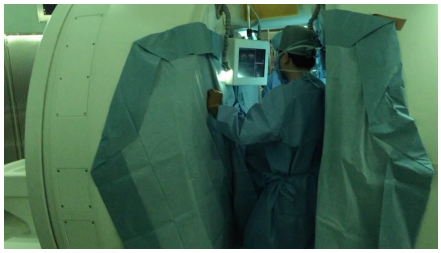
- We can perform wide-categorized experiments by using MR-compatible instruments (energy devices) in the magnet room.
- We can use desktop-class systems in the magnet room by keeping them outside of the 5-gauss line inside of the room.
- We can use the ventilater or other desktop-class systems in the magnet room from the outside of the room because of using the penetration panels.

MRI + alpha:

Interventional MRI
Operation theater

Interventional MRI





Interventional MRI room, Shiga University of Medical Science Hospital

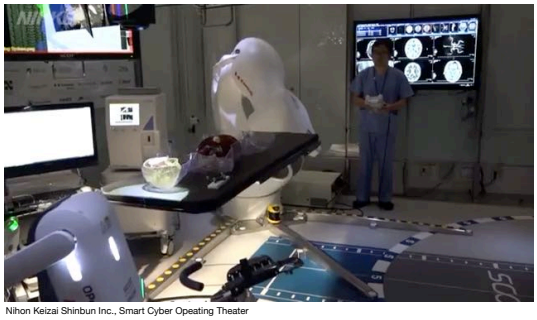
Scanner shutdown

Interventional MRI room after quenching 2022, Shiga University of Medical Science Hospital

Operation theater: Operada Open

Operada Open, FUJIFILM Corp: an operation room with a horizontal open-bore MRI scanner
https://www.fujifilm.com/jp/ja/healthcare/surgery-support/digital-solution-for-surgery/operada-open

Operation theater: SCOT



Nihon Keizai Shinbun Inc., Smart Cyber Opeating Theater
https://www.youtube.com/watch?v=BNUYR4iGDtw

Operation theater: AMIGO Suite

Advanced Multimodality Image Guided Operating Suite (AMIGO Suite), Brigham and Women's Hospital, Boston
https://www.brighamandwomens.org/research/amigo/advanced-multimodality-image-guided-operating-suite

Operation theater: AMIGO Suite

Lengyel B, MD, Introducing the National Center for Image-Guided Therapy

https://www.youtube.com/watch?v=O5ANHBry5hQ

Operation theater: Yamaguchi Univ Hospital

Yamaguchi univ. public relation office, Yamaguchi univ. public hospital

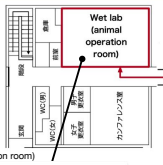
https://www.youtube.com/watch?v=D2Nu8jqtDfU

#3 Scanning process for medium and large-sized animals

Animal scanning process in SUMS

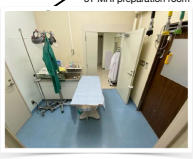
1. A target animal is moved from RCALS (SUMS animal center)
2. Anesthesia is processed in the Wet lab animal operation room.
3. The animal is moved to the 3T MRI room using a plastic bed on a metal cart.
4. The animal with the plastic bed is placed in the scanner bed.
5. The anesthesia machine is set in the machine room to use the penetration panel.

Rooms for animal scanning in SUMS



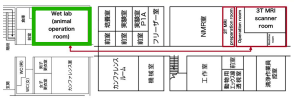
Wet lab (Animal operation room)

3T MRI preparation room



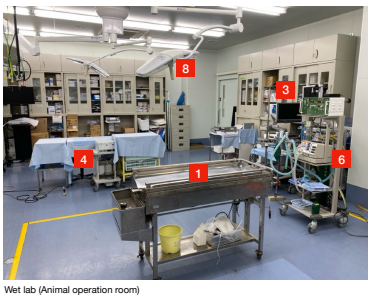
3T MRI room

Wet lab (animal operation room)



Equipements (some of items)

1. OR beds for animals
2. Resin bed for MRI
3. Cardiovascular ultrasound system (Acuson S2000, Siemens Healthcare)
4. Surgical energy devices (Acrosurg microwave scissors, electric scalpels, RF devices)
5. Endoscope systems
6. Ventilator for animals (Compose X, Metran Co., Ltd.)
7. Bed side monitor (BSM-3000, Nihon Kohden Co., Ltd.)
8. Operating lights



Wet lab (Animal operation room)

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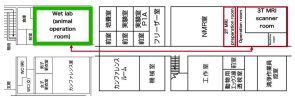

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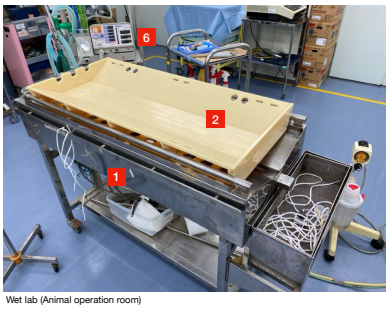
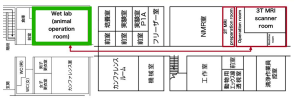


Wet lab (Animal operation room)

Wet lab (animal operation room)



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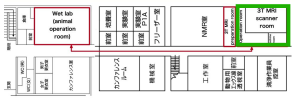
Wet lab (Animal operation room)

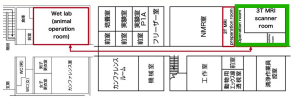
3T MRI room



3T MRI operation room

3T MRI scanner room

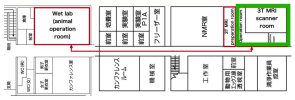
3T MRI room

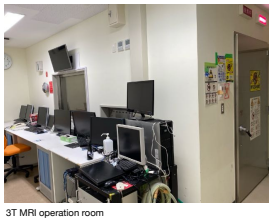


3T MRI operation room

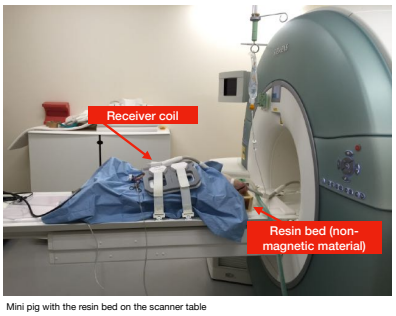
OR bed moved in front of the 3T MRI room

3T MRI room



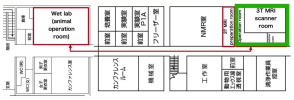


3T MRI operation room

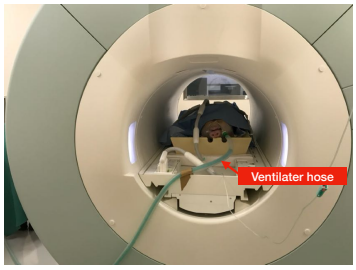


Mini pig with the resin bed on the scanner table

3T MRI room

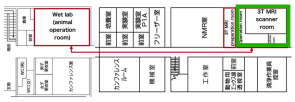


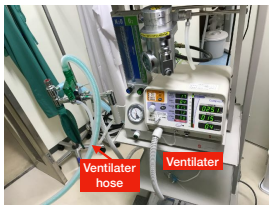
3T MRI scanner room



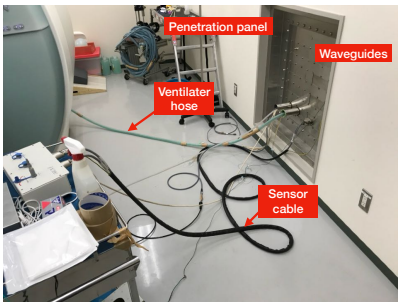
3T MRI scanner room

3T MRI room





Ventilator in the operation room



3T MRI scanner room

#4 Post-processing software

Post-processing software

3D Slicer (https://www.slicer.org/)
A free, open source software for visualization, processing, segmentation, registration, and analysis of medical, biomedical, and other 3D images and meshes; and planning and navigation of image-guided procedures.

ImageJ (https://imagej.nih.gov/ij/index.html)
Image processing and analysis in Java

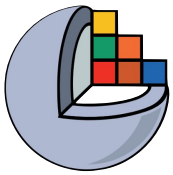
Orthanc (https://www.orthanc-server.com/)
Open-source, light-weight DICOM server

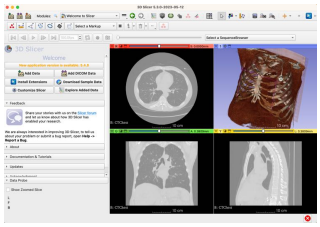
DCMTK (https://www.dcmtk.org/en/)
A collection of libraries and applications implementing large parts of the DICOM standard.

OsiriX (https://www.osirix-viewer.com/)
The world famous medical images viewer

3D Slicer

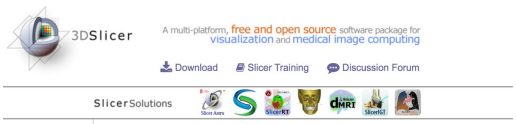
3D Slicer (https://www.slicer.org/)
A free, open source software for visualization, processing, segmentation, registration, and analysis of medical, biomedical, and other 3D images and meshes; and planning and navigation image-guided procedures.





Free open-source software

3D Slicer, OpenIGTLink, CMake, ITK, VTK, Linux etc.

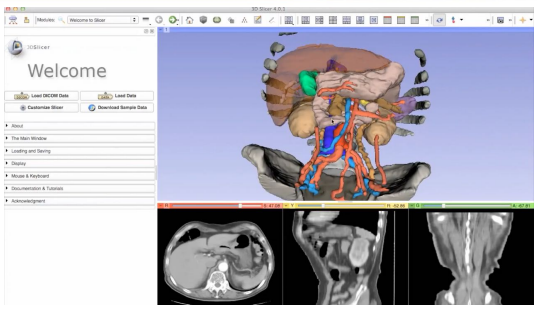


Asset value of 3D Slicer (based on development cost):
- Over one million 3D Slicer's source code lines: 2 or 3 billion yen (20~30億円!)
- VTK and ITK: over 3 billion yen

Total: over 6 billion yen (60億円!*)

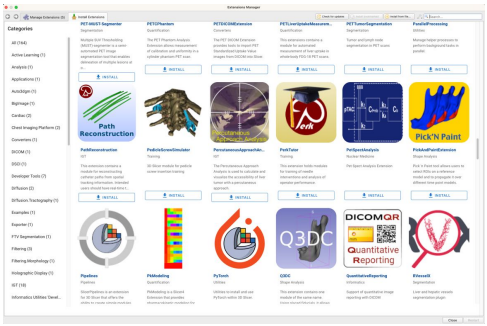
*AZE Special, 波多伸彦, 先端医用画像処理–オープンソースソフトウェアから展開する産学連携体制への期待, https://www.innervision.co.jp/suite_ws/aze/supplement/0906/frontline/index.html

About 3D Slicer



Lengyel B, MD, Introducing the National Center for Image-GUided Therapy
https://www.youtube.com/watch?v=O5ANH8ry5hQ

Module development



Community

National Alliance for Medical Image Computing
A National Center for Biomedical Computing
Funded under the NIH Roadmap Initiative

NA-MIC Project Weeks

Welcome to the web page for the 39th Project Week!

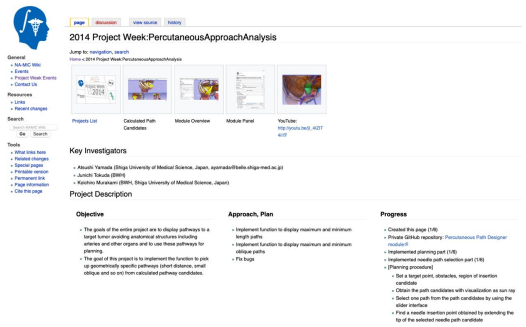
This event will take place June 12-16, 2023 in Montreal, Canada.

- Project Week 39 will be a hybrid event with a strong in-person component
- The venue for in-person events is École de Technologie Supérieure, Montreal, Canada.

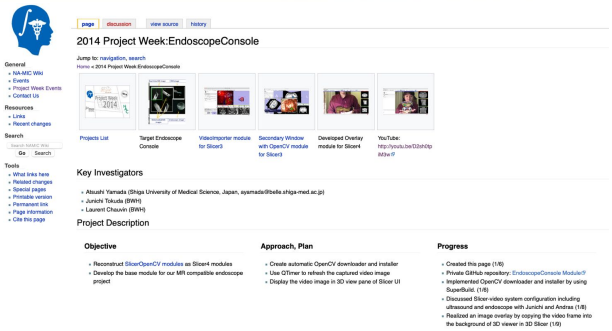
If you have any questions, you can contact the organizers.

NA-MIC Project Weeks

NA-MIC Project Weeks



NA-MIC Project Weeks



3D Slicer

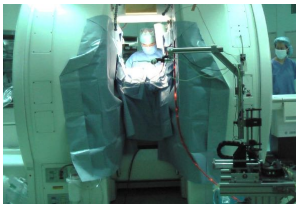
https://www.slicer.org

#5 Research examples

#5-1 Interventional MRI

Microwave Ablation with Robot System

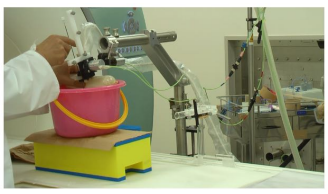
- One surgeon was replaced with a motorized MR-compatible manipulator at the assistant position
- The manipulator guided a needle path
- Applied to 23 clinical cases for MR-guided microwave ablation of liver tumor



#5-2 MR and ultrasound image-guided navigation system using a needle manipulator

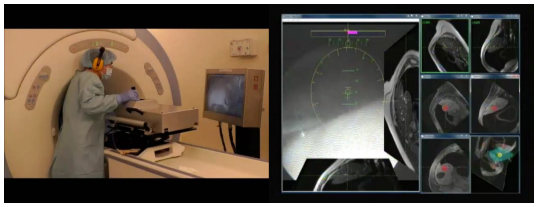
Targeting Procedure

- Decide the needle path to the target by cooperative physician-device interaction
- **Insert the needle while observing MR/US fusion images**



#5-3 Real-time MRI navigation system

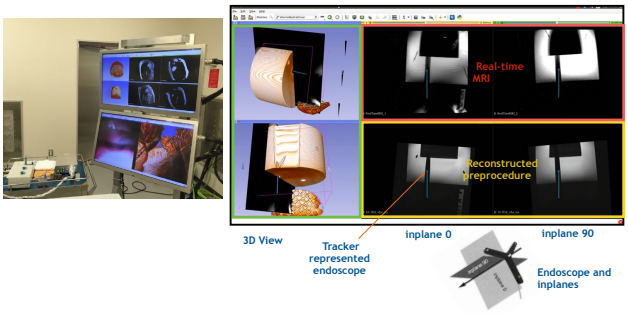
Previous System



Problems

- Fiberscope (low resolution)
- 1.5T closed bore MRI scanner (55cm Inner Diameter)
- Low refresh rate of real-time MRI (1.5 sec/slice)

Real-time MR Navi User Interface



Animal Study

Pig (female, BW 32kg)

4 Surgeons + 1 Engineering Researcher