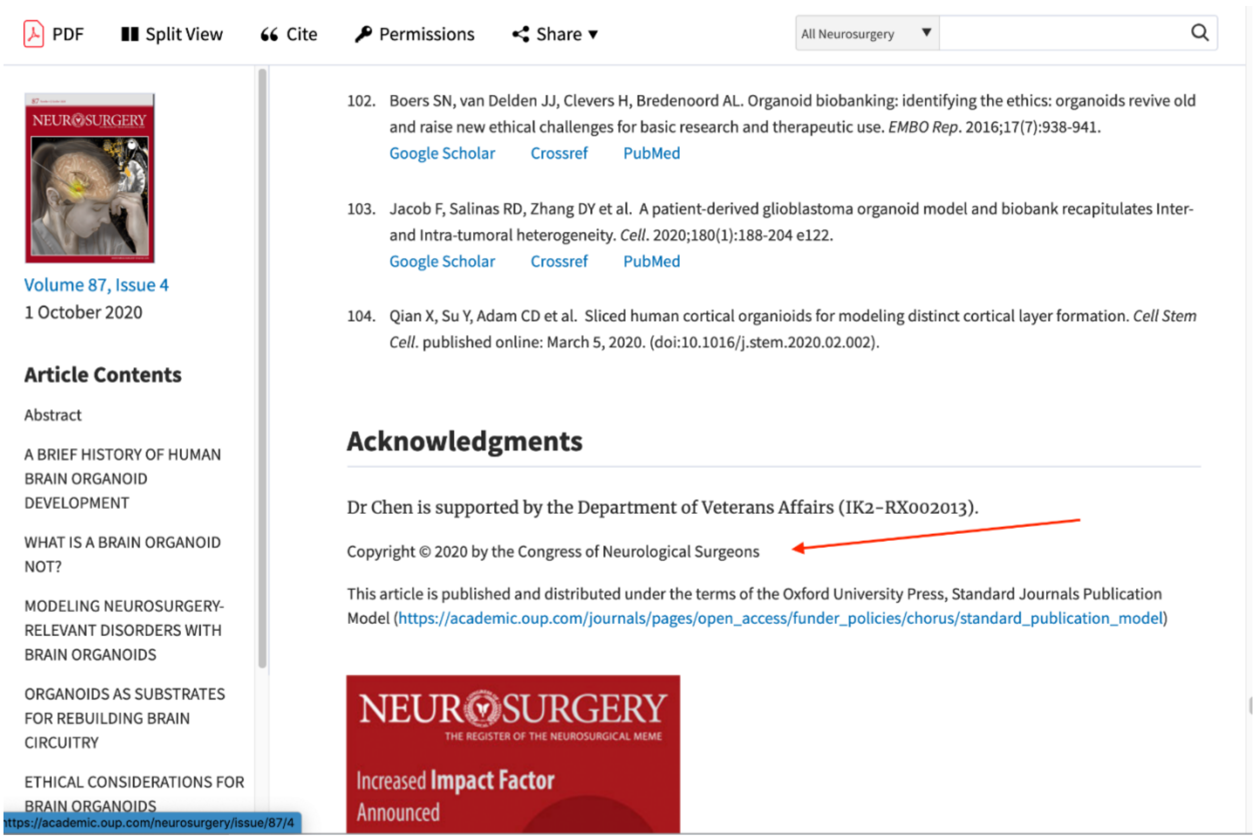
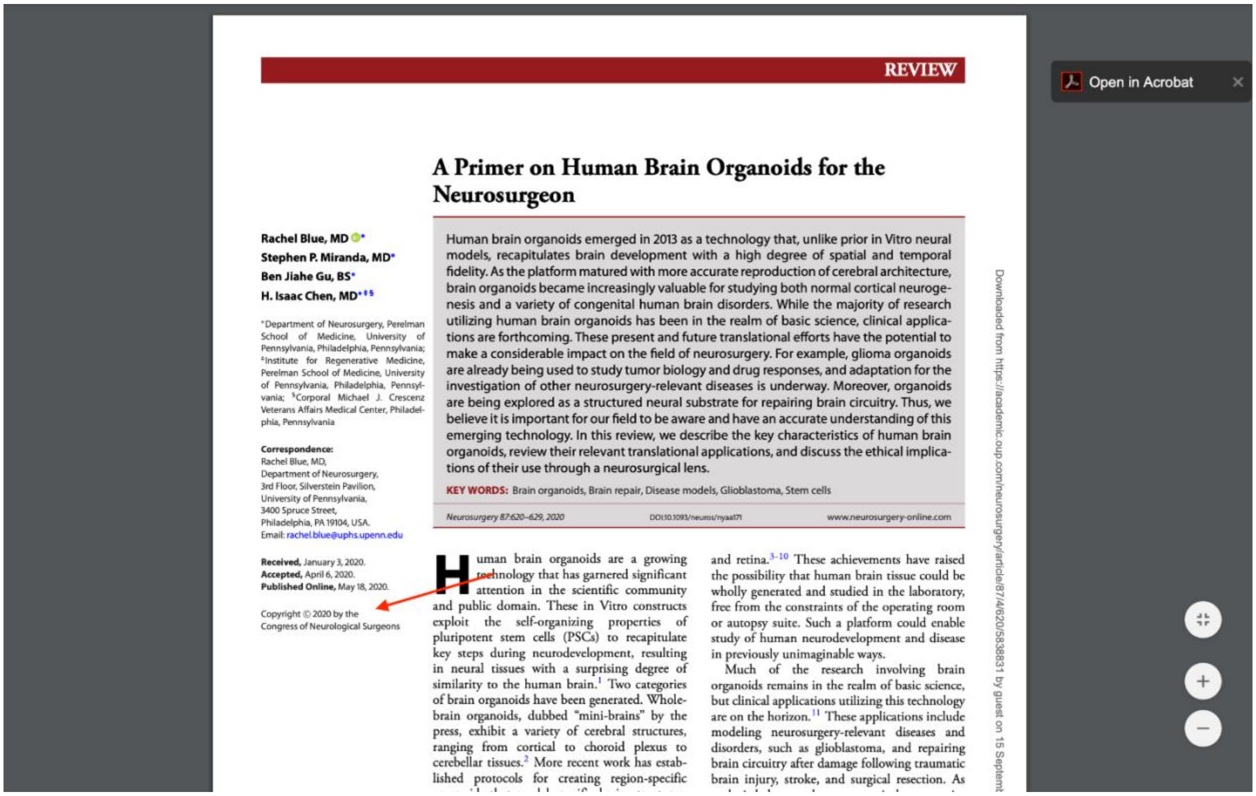
**Accessing Images from Journal Articles at the Article Level**

1. Navigate to your image of choice on the *Neurosurgery* website
2. Click “Download Slide” immediately below the image. This will download the image as a PPT file. This will include the full figure legend as well as bibliographic information for the article.
    a. We’ve established that the Education Division volunteers can reuse content © to CNS without seeking additional permission but this does not apply either to articles copyrighted to another entity, i.e. published Open Access, as a US Government Publication, or under Crown Copyright, or individual pieces of content within an article (i.e. figures, tables, videos, etc.) reproduced from another source. Most of our articles are © to CNS but they should be sure to check the article © line. This can be found at the very bottom of the HTML version of the article (see below)




or on the first page of the PDF version of the article. (see below)



REVIEW

A Primer on Human Brain Organoids for the Neurosurgeon

Rachel Blue, MD[*]
Stephen P. Miranda, MD[*]
Ben Jiahe Gu, BS[*]
H. Isaac Chen, MD[*‡§]

[*]Department of Neurosurgery, Perelman School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania; [‡]Institute for Regenerative Medicine, Perelman School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania; [§]Corporal Michael J. Crescenz Veterans Affairs Medical Center, Philadelphia, Pennsylvania

Correspondence:
Rachel Blue, MD,
Department of Neurosurgery,
3rd Floor, Silverstein Pavilion,
University of Pennsylvania,
3400 Spruce Street,
Philadelphia, PA 19104, USA.
Email: rachel.blue@uphs.upenn.edu

Received, January 3, 2020.
Accepted, April 6, 2020.
Published Online, May 18, 2020.



Human brain organoids emerged in 2013 as a technology that, unlike prior in Vitro neural models, recapitulates brain development with a high degree of spatial and temporal fidelity. As the platform matured with more accurate reproduction of cerebral architecture, brain organoids became increasingly valuable for studying both normal cortical neurogenesis and a variety of congenital human brain disorders. While the majority of research utilizing human brain organoids has been in the realm of basic science, clinical applications are forthcoming. These present and future translational efforts have the potential to make a considerable impact on the field of neurosurgery. For example, glioma organoids are already being used to study tumor biology and drug responses, and adaptation for the investigation of other neurosurgery-relevant diseases is underway. Moreover, organoids are being explored as a structured neural substrate for repairing brain circuitry. Thus, we believe it is important for our field to be aware and have an accurate understanding of this emerging technology. In this review, we describe the key characteristics of human brain organoids, review their relevant translational applications, and discuss the ethical implications of their use through a neurosurgical lens.

KEY WORDS: Brain organoids, Brain repair, Disease models, Glioblastoma, Stem cells

Neurosurgery 87:620–629, 2020 DOI:10.1093/neuros/nyaa171 www.neurosurgery-online.com

Human brain organoids are a growing technology that has garnered significant attention in the scientific community and public domain. These in Vitro constructs exploit the self-organizing properties of pluripotent stem cells (PSCs) to recapitulate key steps during neurodevelopment, resulting in neural tissues with a surprising degree of similarity to the human brain.[1] Two categories of brain organoids have been generated. Whole-brain organoids, dubbed "mini-brains" by the press, exhibit a variety of cerebral structures, ranging from cortical to choroid plexus to cerebellar tissues.[2] More recent work has established protocols for creating region-specific

and retina.[3-10] These achievements have raised the possibility that human brain tissue could be wholly generated and studied in the laboratory, free from the constraints of the operating room or autopsy suite. Such a platform could enable study of human neurodevelopment and disease in previously unimaginable ways.

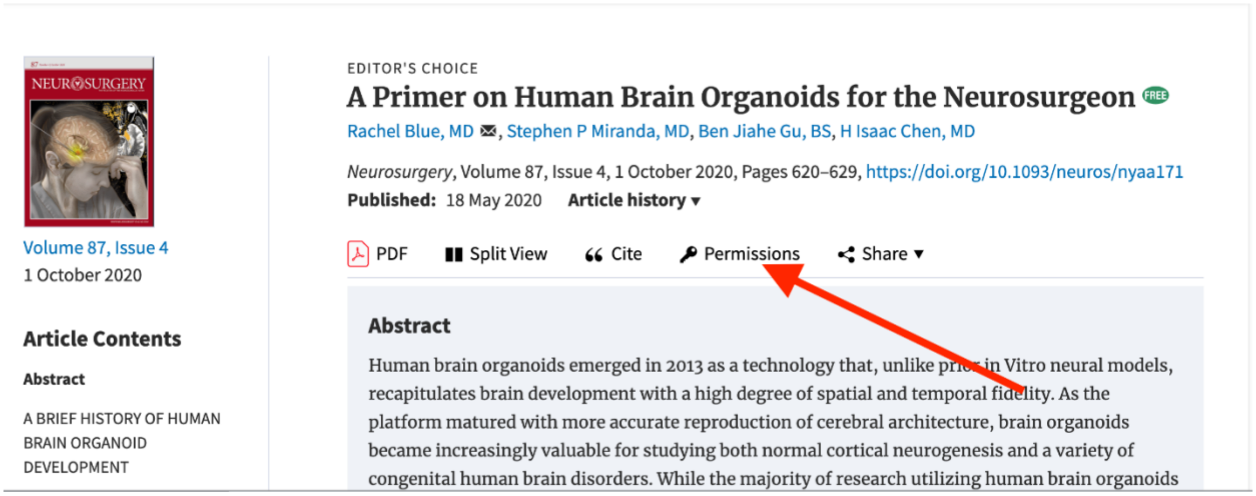
Much of the research involving brain organoids remains in the realm of basic science, but clinical applications utilizing this technology are on the horizon.[11] These applications include modeling neurosurgery-relevant diseases and disorders, such as glioblastoma, and repairing brain circuitry after damage following traumatic brain injury, stroke, and surgical resection. As





If a particular piece of content within an article © to CNS is © to another entity it will be noted in the legend. See Figure 1 in example article https://academic.oup.com/neurosurgery/article/87/4/620/5838831.

You can still use content © to another entity but they will need to secure permission which they can do by clicking the "Permissions" icon at the very top of the article's page (see below).



Volume 87, Issue 4
1 October 2020

Article Contents
Abstract
A BRIEF HISTORY OF HUMAN BRAIN ORGANOID DEVELOPMENT

EDITOR'S CHOICE

A Primer on Human Brain Organoids for the Neurosurgeon

Rachel Blue, MD, Stephen P Miranda, MD, Ben Jiahe Gu, BS, H Isaac Chen, MD

*Neurosurgery*, Volume 87, Issue 4, 1 October 2020, Pages 620–629, https://doi.org/10.1093/neuros/nyaa171

**Published:** 18 May 2020 **Article history** ▾

PDF Split View Cite Permissions Share ▾

**Abstract**

Human brain organoids emerged in 2013 as a technology that, unlike prior in Vitro neural models, recapitulates brain development with a high degree of spatial and temporal fidelity. As the platform matured with more accurate reproduction of cerebral architecture, brain organoids became increasingly valuable for studying both normal cortical neurogenesis and a variety of congenital human brain disorders. While the majority of research utilizing human brain organoids

They will need to be sure to adhere to all requirements listed in the license generated one of which will be including attribution text.

b. For content © to CNS, we ask that full attribution be provided in the resources section of the article: Reprinted from [insert article citation]. Copyright © 2020 by the Congress of Neurological Surgeons."

**Rhoton's**

- The Rhoton book is comprised of content originally published in *Neurosurgery.*
- https://academic.oup.com/neurosurgery/issue/47/suppl_3
- https://academic.oup.com/neurosurgery/issue/51/suppl_4