North Carolina Central University Science & Intellectual Property Law Review

Volume 8 | Issue 1 Article 4

4-1-2015

Man Made Organs: technology Made it Possible but Can the FDA Keep Up?

Amanda Chatman

MAN MADE ORGANS: TECHNOLOGY MADE IT POSSIBLE BUT CAN THE FDA KEEP UP?

AMANDA CHATMAN

INTRODUCTION

A transplant surgeon has five patients that each need a different organ to survive. There are no organs available to perform any of these five transplant operations. A healthy young man comes in for a routine checkup. In the course of doing the checkup, the doctor discovers that his organs are compatible with all five of his dying patients. Suppose further that the young man has no family members or friends and would not be missed if he were to disappear. Should the young, healthy, unattached man die for the greater good of saving five lives? This ethical problem, commonly used in philosophical discussions, is designed to make us consider the effect of one human sacrifice for the greater good. These utilitarian discussions have been occurring for centuries, and other than choosing one life over another, there have not been any real viable answers, until now. The recent advancements in a procedure called bioprinting may make this organ transplant hypothetical moot.

Bioprinting refers to the creation of cartilage, bone, skin, prosthetics, and even living organs using a three-dimensional printing device.[1] Bioprinting is currently used to create prosthetics and training devices for surgeons, but is quickly growing into a source for organs to be used in transplants.[2] Although this amazing technology could solve the transplant problem described above, it also raises numerous ethical questions that could lead to legal bans.[3] The future of bioprinting will depend on how the technology is regulated in upcoming years. History illustrates that regulation is slow to catch up to technology and that will be a major problem for the survival of bioprinting. This comment will discuss the history of bioprinting and its

1. Meghan McCaffrey, *The Stuff of Innovation – 3D Bioprinting and FDA's Possible Reorganization*, WEIL PRODUCT LIABILITY MONITOR (Sept. 10, 2013), http://product-liability.weil.com/news/the-stuff-of-innovation-3d-bioprinting-and-fdas-possible-reorganization/.

2. Lyndsey Gilpin, *New 3D Bioprinter to Reproduce Human Organs, Changes the Face of Healthcare: The Inside Story,* TECH REPUBLIC, http://www.techrepublic.com/article/new-3d-bioprinter-to-reproduce-human-organs/ (last visited Dec. 17, 2014).

3. John Graber, *Report Predicts Possible Ban on Bioprinting 2016*, 3D PRINTER WORLD (Feb. 14, 2014), http://www.3dprinterworld.com/article/report-predicts-possible-ban-bioprinting-2016.

expected growth, the ethical implications, necessary regulation, and the burden on the Federal Food and Drug Administration to adapt and change with this new technology.

BACKGROUND: BIOPRINTING EXPLAINED AND THE CHALLENGES TO THE FDA

Over the past few decades, printing has evolved from two-dimensional printing to an "additive process in which successive layers of material are distributed to form three-dimensional (3D) shapes."[4] Currently, the most common uses of 3D printers are to enable rapid prototyping and manufacturing and to produce personalized products in the home.[5] Three-dimensional printing is also being used in science and education for the purpose of producing replicas of rare artifacts and models of complex molecules and protein interactions.[6]

Charles W. Hugh was the first person to describe 3D printing.[7] His method of 3D printing described the layering of thin materials that could be cured with an ultraviolet light to form a solid 3D structure.[8] This layering process was later used to create "sacrificial resin molds for the formation of 3D scaffolds from biological materials."[9] These 3D scaffolds could be used for transplantation with or without seeded cells.[10] This led to the use of 3D bioprinting as a form of tissue engineering.[11]

In bioprinting, plastic and other materials used to create structures with 3D printing are replaced with sensitive, living biological materials.[12] The biological materials are precisely layered with spacial control of the placement of functional components to fabricate 3D functional living human constructs with biological and mechanical properties suitable for clinical restoration of tissue and organ function.[13] Organ bioprinting is based on stem cells which serve as the initial material for the bio-ink.[14] Stem cells can serve as the building material for any of the body's tissues.[15] The pa-

4. Sean V Murphy, Anthony Atala, *3D Bioprinting of Tissues and Organs*, 32 NATURE BIOTECHNOLOGY 773, 773,(2014), *available at* http://www.nature.com/nbt/journal/v32/n8/full/nbt.2958.html.
5. *Id*
6. *Id*.
7. *Id*.
8. Murphy, *supra* note 4.
9. *Id*.
10. *Id*.
11. *Id*.
12. *Id*.
13. Murphy, *supra* note 4.
14. *World's first 3D-Bioprinted Transplant-Ready Organ to be Unveiled in Early 2015*, RT (Nov. 4, 2014 at 7:55 PM), http://rt.com/news/202175-3d-bioprinted-organ-transplant/.
15. *Id*.

tient's cells are aggregated in layers according to a preset digital organ design to form "spheroids" onto hydrogel.[16] Once the gel dissolves, the "printed organ is placed in to a special bio reactor where it matures."[17] Once the organ matures, it is ready to be implanted into the patient. Since the bioprinted organ is made out of the patients' own cells, the patients' body should not reject the organ.

Although there has not been a human transplant of a solid bioprinted organ to date, surgeons have successfully implanted hollow tissues into patients including skin, cartilage and muscles.[18] There have also been successful transplants of bladders and urethras into young patients.[19] The world's first 3D human liver was printed in 2013 and used solely for research purposes.[20] Despite the fact that many did not expect bioprinted organs to be transplant ready for many years, Russia has announced that its first transplant ready organ, a thyroid, will be released in 2015.[21] Russian Scientists plan to begin their experiment on the thyroid, with further work on a functional printed kidney scheduled for 2018.[22]

In order for bioprinting to be used for the creation of viable transplant organs, it is crucial that the United States Food and Drug Administration (hereinafter "the FDA") adjust its approach to the regulation of new medical technology. Technology grows much faster than the pace at which the FDA regulates. The FDA must take on a more flexible and responsive approach to the regulation of bioprinting technology in order for bioprinting to revolutionize the healthcare industry.

Although bioprinting has the potential to save many human lives through the production of living human organs, without proper regulation it can cause serious harm to both individuals and society as a whole. Bioprinting is a unique hybrid of technology and biology which makes it a difficult area to regulate and oversee.[23] Bioprinting does not fit within a traditional FDA category of "device" or "biologic" and that will require the FDA to rethink

---

16. *Id*.
17. *Id*.
18. *Printing a Bit of Me,* THE ECONOMIST (Mar. 8, 2014), http://www.economist.com/news/technology-quarterly/21598322-bioprinting-building-living-tissue-3d-printer-becoming-new-business.
19. *Id*.
20. Susan Scutti, *First 3D Printed Liver Is Mini But Mighty: Could Transplantable Human Organs Eventually Be Bioprinted?*, MEDICAL DAILY (Nov. 11, 2013, 4:00 PM), http://www.medicaldaily.com/first-3d-printed-liver-mini-mighty-could-transplantable-human-organs-eventually-be-bioprinted-262565.
21. *World's First 3D-Bioprinted Transplant-Ready Organ to be Unveiled in Early 2015, supra* note 14.
22. *Id*.
23. McCaffrey, *supra* note 1.

its regulation process.[24] The FDA took note of this challenge when they decided to form a "Program Alignment Group" tasked to identify and develop "plans to modify FDA's functions, processes, and possibly its structure in order to address these matters".[25] The FDA is attempting to modify their approach to regulation because technology has transformed the devices and drugs being produced today. Their past approach was built around distinguishing products and devices into separate categories, but these categories are now intertwined with one another making their current regulation process less effective.[26]

Although it is clear that this reorganization is necessary, what does it mean for a technology, such as bioprinting, that is in dire need of regulation now? It means that the FDA must make this reorganization effective and do so quickly. A major change in the structure and formation of a government agency's function can be difficult. It can take many years to break up a government agency's existing divisions to adopt new programs. Based on the FDA's history, it does not adapt to change quickly if at all.[27] In 2002, the FDA announced a reorganization that would merge the FDA's drug center with its biologics center.[28] Due to internal resistance to the change, this merger was largely rolled back two years later.[29] Not only does the FDA face the challenge of reorganizing its regulation methods, it must also overcome the internal resistance it will face in order to allow new technology such as bioprinting to reach its potential as a health care tool.

There are "currently no government regulations on bioprinting, bioprinted products or the machines."[30] The FDA has only addressed the regulation of 3D printed medical devices that do not involve living biologic materials.[31] In recent years, it has become common practice to use 3D printers to produce customized devices such as hearing aids, dental implants, and surgical instruments.[32] Although these 3D printed medical devices have become common, the FDA has yet to create custom regulations

---

24. *Id.*

25. Scott Gottlieb, *Did FDA Just Announce A Major Reorganization?*, FORBES (Sept. 8, 2013, 6:27 PM), http://www.forbes.com/sites/scottgottlieb/2013/09/08/did-fda-just-announce-a-major-reorganization/ .

26. *Id.*

27. *Id.*

28. *Id.*

29. *Id.*

30. Meghan Neal, *3D Bioprinters Could Make Enhanced, Electricity-Generating 'Superorgans'*, MOTHERBOARD (June 13, 2014, 1:15 PM), http://motherboard.vice.com/read/3d-bioprinters-could-make-enhanced-electricity-generating-superorgans.

31. *How should FDA treat 3-D printing?*, THE ADVISORY BOARD COMPANY (Sept. 5, 2013), http://www.advisory.com/daily-briefing/2013/09/05/how-should-fda-treat-3-d-printing.

32. *Id.*

for such products.[33] The FDA currently assesses "3D printed medical devices and conventionally made products under the same guidelines, despite the different manufacturing methods involved."[34] The FDA is just now beginning to consider different methods for regulating 3D printed devices and have yet to officially implement new procedures. It is vital that the FDA take a more proactive approach to regulating the use of bioprinters. Since bioprinters combine human cells with 3D printing technology, leaving regulation as it is and only tweaking it once the technology is commonly used would likely result in a dangerous outcome.

FDA regulation is necessary because bioprinting raises many ethical questions that involve the well-being of patients and society as a whole. There are questions that need to be heavily discussed and answered before bioprinting of living organs can become a reality. One of the most alarming questions regards the possibility that bioprinting could lead to "dystopian immortality in individuals that can afford to have organs repaired or replaced as they wear out."[35] Although attainable immortality in itself may seem like an overwhelming thought, what is more concerning is the effect this could have on society. It is most likely that money would decide who receives a new organ and who does not, which translates into money determining who lives and who dies.[36] The cost of functional organs produced from a bioprinter will only be available to those financially capable of paying for such personalized treatments.[37] This will continue to expand the access divide between the rich and the poor.

Regulation is necessary to control the purpose of bioprinting. Another issue to be regulated is the possibility that bioprinting could become related to performance enhancement in professional sports.[38] Athletes will have the capability to use bioprinting as a tool to repair injured tissues or muscles or even replace natural muscles with synthetic ones which could unnaturally advance human capabilities.[39] This could also lead to the use of bioprinting for cosmetic purposes. Individuals could design their own nose, ear, or chin as opposed to trusting the plastic surgeon to construct one out of their existing body parts. Although this may not seem extreme, where does it end? If there are no restrictions on the use of the body part or the

33. *Id.*
34. *Id.*
35. C. Waldo, *Bioprinting* (Sept. 25, 2012), http://ethicsof3dprinting.weebly.com/bioprinting.html.
36. *Id.*
37. Richard Adhikari, *Bioprinting, Part 2 – The Ethical Conundrum*, TECHNEWSWORLD (Mar. 27, 2014), http://www.technewsworld.com/story/80205.html.
38. Waldo, *supra* note 35.
39. *Id.*

amount created, it is plausible that bioprinting could lead to the construction of a synthetic human.

Another issue that is likely to result from the bioprinting of organs is the illegal buying and selling of synthetic organs. Just as there is currently a black market for human organs, a bioprinted black organ market may result from the advancement of bioprinting.[40] The possibility that individuals will bioprint organs to make a profit is potentially more dangerous than the current black market that distributes human organs. Bioprinted organs are designed and manipulated by a person and then produced by a machine. There are many more opportunities for error when the organ is being constructed by man and machine than there are when dealing with a human organ.

ANALYSIS: THE SOLUTION

Although the bioprinting of human organs has not yet been used in human transplants, the issues that must be dealt with when bioprinting is commonly used are readily apparent. The FDA needs to alter its regulation approach and begin putting regulations in place now that will guide the mainstream use of bioprinting rather than waiting until the damage has already been done. The FDA should: (1) develop a detailed plan regarding how bioprinted organs will be distributed; (2) develop guidelines for determining the eligibility for the allocation of bioprinted organs and tissue; and (3) determine who will control and monitor the production of human organs.

(1) Developing a detailed plan regarding how bioprinted organs will be distributed

The FDA currently regulates human cells or tissues intended for implantation, transplantation, infusion, or transfer into a human recipient, while The Health Resources and Services Administration (hereinafter "the HRSA") oversees the donation and transplantation of vascular organs, such as hearts, livers, and kidneys.[41] The HRSA governs the entire organ donor process from placing a patient on the waiting list, to matching the patient to an available organ, to the transplant surgery. Bioprinting technology will drastically change the process of events for patients in need of an organ and this will create the need for a new process in the acquisition of a new organ.

---

40. *Id.*

41. *Tissue and Tissue Product Questions and Answers*, FDA http://www.fda.gov/BiologicsBloodVaccines/TissueTissueProducts/QuestionsaboutTissues/ucm101559.htm (last updated Dec. 16, 2014).

Patients will no longer have to go through the process of being put on a waiting list, waiting to see if a person who is a match for their specific transplant dies, going through the transplant surgery, and then waiting to see if their body accepts or rejects the organ. Although there has yet to be determined an exact process regarding the patient experience with bioprinting, it is likely that a doctor will remove cells from the patient and have those cells used in the production of the necessary organ. Once the organ has been produced, the doctor will remove the defective organ and replace it with the bioprinted organ. The bioprinting process revolves around the doctor and the bioprinter. There is no longer a third party involved, nor is there a risk that the patient's body will reject the organ.

Since bioprinting is centered on the bioprinter itself, which is a device, it would be more efficient to have the FDA regulate the organ donor process as opposed to the HRSA. The FDA already regulates human tissues, and medical devices. Bioprinting combines a medical device and human cells and tissues to create the organ to be transplanted. Therefore, it seems most reasonable for the FDA to maintain the utmost control over the safety of the transplants and the distribution of the organs.

The method of distribution will determine whether the ethical issue of "dystopian immortality" truly becomes a reality.[42] In establishing a distribution plan for bioprinted organs, it is crucial that the FDA find a middle ground between the economic requirements of this technology and those in need of bioprinted organs. The FDA must prevent bioprinting from becoming a luxury for the wealthy. It must be integrated into the health care system in order to become available to individuals of all economic classes.

The FDA should take an approach similar to the current system in which patients receive organs according to their position on a list. The main difference exists in recognizing that patients are no longer waiting for a match, but are waiting for a custom creation of an organ made from their own cells. It may be effective to separate patients into two groups; those in imminent need of an organ and those that can survive without an immediate transplant. This separation would mirror how hospitals separate patients, in that those in need of critical care are in the intensive care unit while patients with less serious injuries or illnesses are not in a specialized unit. This separation would allow the appropriate attention to each patient depending on their condition, absent regard to their economic status. Patients would not be able to buy their way into a bioprinted organ because their treatment would be based on their specific condition. Although the cost of the bioprinted organ itself may have an effect on who is able to receive it, in-

42. Waldo, *supra* note 35.

surance companies and their regulations regarding bioprinting would deal with the issue.

(2) Developing guidelines for determining the eligibility for allocation of bioprinted organs and tissue

Determining who is and is not eligible for donor organs has always been a controversial issue. Based on the number of patients in need of a donor organ and the few organs that become available, eligibility is determined by a number of psychosocial factors, including age, mental health, and intelligence.[43] Allocation decisions have been made by donor programs, hospital administrators and even physicians.[44] This method has contributed greatly to the accusations of bias allocation and discriminatory allocation.[45] This method would likely be just as inconsistent when dealing with bioprinted organs.

As suggested by many medical professors and professionals, government entities may "have the strongest claim to authority to make organ allocation decisions."[46] Although this solution does not guarantee complete fairness, by setting out allocation guidelines prior to the mainstreaming of bioprinted organs, there will be infrastructure for assuring that this technology is being used in the proper situations.

Currently, one of the largest issues regarding organ allocation is that patients with disabilities are being discriminated against. Although this issue may exist when bioprinting is used for organ transplant, a larger concern is that bioprinting will be used for cosmetic or advancement purposes. There must be limits set on what type of replacement or treatment bioprinting will be used for in order to avoid the unnatural advancement of human capabilities.[47] The most effective way to do this is for the FDA to begin setting those limitations now.

There are two sides to the creation of enhanced organs, also referred to as "superorgans."[48] The first is the idea of creating organs that have the capabilities to fight off disease or contribute to the health of the human body. The possibility of engineering artificial organs to perform specific, useful functions, such as treating disease is already being discussed by scientists.[49] In fact, a 3D printed artificial pancreas that can regulate glucose levels in

43. Joel Frader, *Re-evaluating the Recipient Criteria for Organ Transplants*, 41 PEDIATRIC ANNALS 135, 135 (Apr. 2012), *available at* http://www.healio.com
44. *Id.*
45. *Id.*
46. *Id.*
47. Waldo, *supra* note 35.
48. Neal, *supra* note 30.
49. *Id.*

diabetic patients is being developed at the University of Iowa's Advanced Manufacturing Technology Group.[50] Scientists are thinking as extreme as bioprinted organs that can generate electricity in the human body in order to power electronic implants like pacemakers without the need for batteries.[51] These functions seem reasonable in that they intend to contribute to human health.

The second side of the creation of "superorgans" is the idea that body parts can be created to allow for performance or cosmetic enhancements. There has been a battle in the professional sports industry for years against the use of performing enhancement drugs, such as steroids. Bioprinting technology could potentially be used for performance enhancement purposes and could easily exceed the capabilities of any existing performance enhancing drug. Bioprinting would allow the creation of new muscles with capabilities that surpass those of natural human muscles even with drug enhancements. Not only could this be a problem for professional sports, but it could be an issue for law enforcement. If individual citizens were able to acquire superhuman muscles, traditional police powers may not have the same control over them, thereby creating a threat to the safety of others.

The FDA should limit the use of bioprinting to the replacement of organs and tissue necessary for the survival of patients during the first few years of its use. Once the number of individuals in need of a bioprinted organ is under control, the FDA should expand its eligibility requirements to include patients seeking a bioprinted transplant for the purpose of improving human health. The FDA should have strict regulations in place to prevent the use of bioprinters for muscle or organ enhancement for the sole purpose of improving physical performance.

(3) Determining who will control and monitor the production of human organs

One of the greatest problems regarding bioprinting is the factor of control over the production of organs. Control is necessary to prevent the creation of unauthorized "superorgans," a bioprinted organ black market, and to ensure a safe transplant process. The FDA's regulations regarding the control over the production of bioprinted organs is what allows them to enforce the other regulations discussed above.

The FDA should suggest the establishment of an agency that will oversee bioprinting production. This agency will be responsible for the enforce-

50. *Id.*
51. *Id.*

ment of regulations regarding allocation of bioprinted organs, the order in which organs are distributed, consultation with insurance companies to establish a fair process for affording bioprinted organs, and ultimately have control over each functioning bioprinter.

Bioprinters, like any printer, function through a software program. In order to be aware of what organs have been printed, the patients they have been printed for, and where they have been printed, the agency should create a software used by every bioprinter. This software will allow the agency access to regulate the use of the bioprinters without having physical control of the bioprinting process. The agency would require that each bioprinter manufacturer install its software on each machine in order for the machine to be approved by the FDA. The agency would then be able to review how each bioprinter is used and on which patients. The software would require the input of each patient's personal information and the reason the organ is being created for the patient. There would then be a follow-up process to ensure that the patient actually was in medical need of the bioprinted organ and did in fact receive the organ. This process would prevent facilities with access to bioprinters from abusing the technology. By having remote access to every function of the bioprinters, the government will be able to effectively regulate the use of this new technology.

CONCLUSION

There is a need for immediate government regulation of bioprinting. The FDA has a habit of waiting for the technology to become mainstream prior to issuing regulation. This method of regulation is insufficient with regards to new, advanced technologies, such as bioprinting. It is important to remember that although bioprinting is the use of a printer to create a body part, the product is a living organ or tissue that will be implanted into the human body. The FDA must adapt to changing technology and begin developing regulation now. It is vital that the FDA considers how these bioprinted organs will be distributed, what conditions will make an individual eligible for bioprinting, and how to control the production and distribution of bioprinted organs. Bioprinting has the potential to change how we look at organ transplants, but in order for it to be a successful method, the FDA must be proactive in regulating the technology.