

Should Society Encourage The Development Of 3D Printing, Particularly 3D Bioprinting Of Tissues And Organs?

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Abstract: My aim is to discover moral and ethical sides of 3D printing which is a new technology and, paradoxically, a new phenomenon of the twenty-first century. Particularly, 3D bioprinted organs and tissues is a controversial issue, because this technological advancement may be viewed by society as a servant or it can even potentially become its master. For example, in the health care system, doctors may change their attitude to patients by using 3D bioprinted organs and tissues whenever it is needed, also, taking away responsibility from patients. Thus, there can be great social and psychological consequences from 3D bioprinting in a long term. Furthermore, Pete Basiliere, an analyst in a world's leading information technology research company, suggests that 3D printing can also bring economic consequences, resulting in the loss of at least \$100 billion in intellectual property theft per year by 2018 globally. By analysing the economic, psychological and social impact of the 3D printing technologies, I want to research whether anyone is going to be responsible for the 3D printing production and who is going to give a right to 3D bioprint.

Introduction

The development of medicine has already made it possible to perform organ transplantation in animals and human beings in the first half of the twentieth century. This was a significant achievement of humanity and it can be considered as a significant milestone in the science's development, including the psychological aspect of it, since individuals got a chance to live life to the fullest after surgery. Advances in the 3D printing technology of the early 21st century have radically changed the ability to cure ailments and created preconditions for the transition to the next stage in the development of medicine. The purpose of my independent research is to carry out a comprehensive analysis of possible consequences for society in terms of a medical practice, provided by the 3D printing technology of biomaterials, humans and animals' organs. Dr. Josep M. Grinyó, the Chief of Nephrology at the University Hospital of Bellvitge, describes this phenomenon in "Why Is Organ Transplantation Clinically Important?", putting forward a well-considered point of view that "organ transplantations have gradually ameliorated in the last two decades and usually provide excellent results in children and young adults, and are increasingly challenged by the growing proportion of elderly transplant patients with comorbidities." (1) Even though the author's language is free of emotion-rousing words or bias, Dr. Josep M. Grinyó considers only positive sides of organ transplantation, meaning that the article is not balanced. However, the establishment of a transplantation industry led to a number of negative consequences, implying that human organs and tissues have become the object of commodity-money relations. Leading to the formation of the poorly transparent market of human organs and human traffic, which is largely under the patronage of criminal networks. The human beings' organs are being trafficked all over the world, sometimes with, and sometimes even without, the consent of those to whom they belong. Furthermore, as suggested by a reliable source, Stephen Wilkinson, a Professor of Bioethics at the Lancaster University, "there is an increased risk that consent will be flawed in sale cases; if organ removal proceeded without proper consent then that could be a failure to respect the person." (2) Relevant author's expertise and experience of reproductive ethics and the regulation of reproductive technologies would strengthen

the claim that organ transplantation has not only positive sides (organ trafficking is as an example of such harm to society), because his expertise would enable him to make an empirical point. In addition, Nancy Scheper-Hughes, a Professor of Medical Anthropology at the University of California, claims that in any given year, fewer than 1 in 10 waiting for a donor organ will receive one. (3) Therefore, humanity faces the moral and ethical paradox: high humane goal of the improvement of individuals' lives is solved at the expense of someone else's health or an entire life itself of other human beings. This process is accompanied by the formation of a material and financial enrichment of different kinds of intermediaries who control the market of human organs. Ethical issues in the development of transplant are the subject of perennial debates for many decades. This moral and ethical paradox of transplantation is reflected in the literature. From the philosophical perspective, there was an attempt made by Mikhail Bulgakov, an outstanding Russian writer, to understand the effects of the transplantation of human and animal organs' in the satirical fantasy "Heart of a Dog", written in 1925. In the novel, the author has described the tragic effects of the successful surgery from the medical view: the transplantation of the deceased person's pituitary gland in a dog, called Sharik. The results exceeded expectations, the dog started to behave as a human being, but later it turned out that the dog was rude, just like the donor of the organs, Klim Grigorievich Chugunkin, who was a bully and an alcoholic. "The whole horror of the situation is that he [Sharik] now has a human heart, not a dog's heart. And about the rottenest heart in all creation!" (4) This shows how unpredictable the process of transplantation is from the ethical perspective; even more, there are also no guaranteed results. For example, the National Center for Biotechnology Information in the USA states that there was a case, when a woman had sudden circulatory collapse with abdominal pain the day after liver transplantation, making the claim about unpredictability of the process plausible. (5) There are some areas around the phenomenon are also to be considered, showing that 3D printing in general is not a perfect technology yet. 3D printing cannot always guarantee the result and sometimes it cannot even replicate its original as a result of 3D copying. This is a technology for the implementation of a

methodology for obtaining the original images, considered as copies, which corresponds to the set of requirements in terms of a certain quality criteria. In particular, human stem cells and completely synthetic ingredients can be used as the original material for copying organs for transplantation. According to Lyndsey Gilpin, a former writer for TechRepublic, there are already 3D bioprinted organs and tissues "from prosthetic limbs and various surgical devices made with plastics and metals, to using cells to print human organs". (6) TechRepublic, the largest online community of IT leaders, has a positive reputation, which is widely seen as delivering accurate information from a vast library of professional resources in the given industry. In addition, initially in the manufacturing process there can be a task to get rid of some pathologies, the actual reason for surgery. It is not as simple as just making a copy of an organ, because doing this will also replicate a disease. Thus, the qualitative characteristics produced by 3D printing technology can significantly differ from an original object or an organ.

Macroeconomic aspects of the mass distribution of 3D printing technology

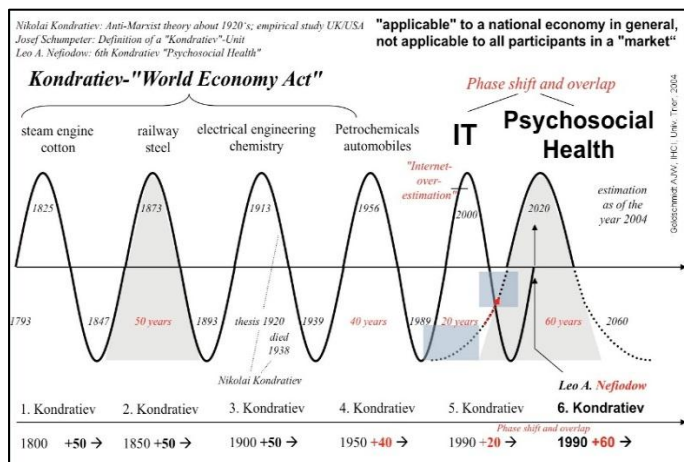


Figure (7). Kondratiev waves associated with gains in IT and health with phase shift and overlap, Andreas J. W. Goldschmidt, 2004.

Nikolai Kondratiev's theory of "long waves" in economics (commonly referred to during global economic crises) looks at long cycles as a feature of the economic activity of capitalist nations and periods of self-correction. Now the modern world economy is at the stage of transition from the fifth to the sixth technological order, consider figure (7). Furthermore, the Slovak theorist Daniel Šmihula, who has an educational background in this area, predicts that "the next decades-long phase as the post-informational technological revolution is to begin between 2015 and 2020". (8) Additionally, The World Economic Forum's Global Agenda Council on the Future of Software & Society asked more than 800 executives and experts from the information technology about 3D printing, the majority of respondents believe that it is "the birth of a new industry supplying printing materials, a rise in entrepreneurial opportunities and environmental benefits from reduced transportation requirements". (9) Who knows, perhaps, this claim is plausible or even correct that 3D printing,

particularly in relation to transplantation, might be one of these technological innovations that will act as the driver for the next quantum leap in the development of our civilization for the next few decades. As it has already repeatedly happened in the history of our civilization, a technological breakthrough in one local segment can cause a multiplier effect and can become a prerequisite for the rapid development in a number of related fields, including applied science and technology. Based on the consideration of the economic theory described above, investment needs for the apparent boundless markets initially, arising from the massive use of these technological innovations in various fields of human activity. It may lead to the concentration of significant financial resources for their development in the next 10-20 years. Forbes, an American business magazine with a positive reputation, states that investments create "new innovation paradigms that will return the U.S. to much higher rates of economic growth." (10) As shown in the figure (7), a similar phenomenon occurred five times in our recent history, so there is reason to assume with a high probability that we are witnessing its recurrence once again. Moreover, the direction of such significant investment flows can occur even without any stimulating effect on the part of states, governments or influential international financial institutions, and by the very nature of commodity-money relations, capital flows into those areas where its location provides the maximum rate of return. The emergence of fundamentally new high-tech branches in industry, in turn, will lead to a need for a large number of qualified employees who must possess an appropriate level of training and qualifications. This is acts as an incentive to improve the entire higher education and a vocational training system, as professionals employed in this industry must be well-qualified, undoubtedly demanding knowledge. In our current understanding, this knowledge is considered as different branches of applied science as part of the educational systems around the world. Learning Network on Capacity Development, a non-profit organisation, makes an argument that training acts as an actual incentive to stimulate changes, as in this case, related to a technological progress. (11) At the same time, one should also consider that 3D printing, as well as any other technological innovation, is unable to be a panacea for all the problems of humanity, it can only act the role of a locomotive at a certain stage of historical progress, not for the whole history of humanity. Inevitably, there comes the day (according to Nikolai Kondratiev's economic theory of "long waves" after 20-25 years after the onset of mass application) when the dominant technological innovation ceases to play the role of a growth driver. (7) Moreover, by that time the technology is not going to be considered as unique, it is just an ordinary technology that is used on daily basis, eventually becoming the first cause of the protracted crisis on a global scale. Since by this time the market is saturated with products manufactured by this technology, and investments in this area are no longer bear at least the minimum justified rate of return. According to Panos Mourdoukoutas, publicised by Forbes, that this will happen, once 3D printing becomes mainstream and money pours into the 3D printer technology to make these printers faster. (12) The way out of this economic crisis is possible only after another revolutionary technology appears on a global scale, which can replace a predecessor and can eventually

become the locomotive of the world economy for the next few decades. Society should be prepared that at the stage of formation and mass distribution of 3D printing technology there is going to be an inevitable emergence of significant imbalances in the labour market because of its reformatting to fit the new realities. On the one hand, until there is an established system of higher education and vocational training for the mass training of specialists in the field of 3D printing, the labour market may witness possible shortage in employees who are able to organise the production of 3D printers for different applications and provide them with competent service. (11) Nevertheless, the mass use of a new technology will inevitably lead to a large reduction of the currently existing traditional industries, there is going to be an emergence of a significant number of professionals coming from the different qualifications in the labour market who will not be in demand anymore in the new conditions. Of course, a certain portion of them will be able to find a use by filling vacancies without any problems for new productions as, most likely, low-skilled part-time workers. Regarding the rest of those who ended up unemployed due to the formation of the new structure of the economy, society will take measures for their rehabilitation and social adaptation to new realities. It is also worth noticing that there is not enough research about this particular area of a 3D bioprinting phenomena, since right now 3D printing is only going to become the technology of mass use. Brian Krassenstein, a co-founder of 3DPrint.com, believes that to see what actually 3D printing may lead to, there should be "at least a 100,000% rise in the adoption rate by manufacturers as current estimates for the total value of the 3D printing space sit at" and also "It will certainly take time before 3D printing becomes mainstream." (13) Although the author has a positive reputation in this area and he appeals to authorities in his article, he clearly has a vested interest in this area, making his claim biased.

3D printing in transplantation and related moral problems in society

Modern transplantation is mainly based on the transplantation of organs from a human donor to a human recipient. Typically, the donor is a deceased person, or a certain person that made a decision to sacrifice his or her health because of specific circumstances for the recovery of the recipient. It should also be acknowledged that there are cases in which the donor is a person that happened to be a victim of criminal structures, working in this area, meaning the operation of transplantation is against the will of a person. For example, there was a case in China, where a group of 16 people, including doctors, were selling kidneys illegally; receiving organs from people from disadvantaged backgrounds "for approximately 3,000 Euros for an organ, while the doctors selling it for 24,000 Euros". (14) In any case, a person who is a recipient in this case and society as a whole raise questions related not only to a legal perspective, but also to the moral side of such medical operations. Unfortunately, the situation described above is not unique in China. Arthur Caplan, professor and head of the Division of Bioethics at NYU Langone Medical Center, believes that "the part of the solution to the problem in China is to put pressure on the Chinese to comply with international norms for ethical organ transplantation", since China is sensitive to pressure because it is a part of the

international community. (15) Arthur Caplan is a distinguished researcher who has an expertise in this field, making his argument plausible and strengthening the claim. In this context, it is clear that the production of synthetic 3D printed organs for transplantation removes from the agenda the whole range of very controversial issues of moral and ethical issues, regarding the origin of used organs and biomaterials. However, it can be predicted that as a result of the spread of 3D printing in transplantation, humanity can further aggravate psychological problems that we already witness in society, or exacerbate those that are considered as latent at the present moment. According to Medscape (a reliable source of information due to the experts with empirical evidence publicising there), an example of such problem can be "psychological acceptance of the transplant and, for cadaver donation recipients, dealing with the fact that someone lost their life just when they regained theirs". (16) Philosophical thinking is still not developed in the theme of human transformation due to the fact that the qualitative characteristics of the object, produced for transplantation, may significantly differ from the original organ. Therefore, it becomes possible to have combined feelings: the loss of some other qualities of a human recipient and the acquisition of the others. Thus, changes can be pre-programmed either purposefully or spontaneously. Following this, now it already seems a real problem in the near future that was previously described by many science fiction authors about the origin of people that have some parts of the body, created with the use of biorobotics; such situations were described in "The Future Is Short: Science Fiction" by Paula Friedman. On the other hand, the opportunity of purchasing synthetic organs to replace disease-prone ones may mislead people and create an illusion that there is no need to protect and care about personal valuable health, taken it for granted. Since in the case of a premature loss of the organ or the part of the body, it can be relatively simple and not expensive to buy a new healthy organ with money. Special consideration is given to the category of so-called computer gamers. In recent decades, mass distribution of personal computers and associated computer games have led to the situation, where society already witnesses several generations of people for whom the virtual computer world has become almost reality. Keele University produced a research that those who regularly play violent games are more tolerant to ice cold water or pain, compared to those who play non-violent games. (17) For this type of people, it became normal (for some even part of their daily virtual routine) to harm other people in the computer game, other bodies, or even kill an opponent and to get injured or be killed, and then somehow to buy or win bonuses to be able to heal or resurrect again. For example, Parenting.com describes a wildly popular violent video game, Mortal Kombat, as "the game that includes the most realistic and gory graphics that go way beyond what you would expect". (18) The latest version of the game includes enhanced graphics with violent killing sprees. According to Steam Charts, an ongoing analysis of Steam's player numbers, Mortal Kombat had 13,649 peak users in April 2015. (19) In this regard, the statistics provided by the website with reliable data actually explains the reason why psychologists, such as Dr. Christopher J. Ferguson, are concerned about the depreciation such eternal values as health and life from the

active computer players' perspective. Therefore, the appearance of opportunities in reality, such as simply buying 3D printed biomaterials and bodies to treat, is likely to result in diminishing of the line between the virtual world and reality in the computer gaming environment, and as a consequence – from gamers' point of view, to even greater depreciation of life and health, their own and others.

3D printing in transplantation and the quality of life of the average person

The products manufactured by 3D-printing technology are already used in medicine. However, while the cost of such biomaterials is high, its usage is now is at the testing stage. It can be assumed that the mass production of 3D printers will lead to a dramatic reduction in the value of printers in general, and the products produced. The use of 3D printed products in transplantation will raise the quality of life of the average person. Also, if the development of this technology is successful, then, in the vast majority of cases, an individual will no longer need to spend a lot of money on expensive, and often ineffective, treatment of diseases, and instead will be able to get rid of the illnesses with more affordable means. Thus, it will be possible to increase the life span of the average person, and its quality, providing an opportunity to use savings or other resources from the treatment to satisfy other spiritual and material needs. It is also necessary to warn people about unreasonable expenditure on rejuvenation, because not everyone will be able to deal adequately with the new-found opportunities, mistakenly assuming that 3D printing technology is the way to immortality. Since ancient times, attempts were made to get the elixir of life, the most famous Chinese alchemical book, written in c. 581 — c. 682 CE, "Essential Formulas of Alchemical Classics" attributed to Sun Simiao discusses in details the creation of elixirs for immortality, these attempts do not cease to this day. (20) The media periodically informs about the wealthy people, who spend quite fantastic amounts of money on a variety of wonderful techniques to increase the duration of their lives. For example, a famous American model Cynthia Ann Crawford considered an effective therapy for maintaining youthful metabolism. There are also cases when even middle-class people are selling all their possessions, becoming obsessed with an idea to rejuvenate by endless cosmetic surgery. Therefore, society should take measures to ensure that such precedents do not become a phenomenon of the twenty-first century, related to the development of 3D printing technology. Society should control mass media to prevent the promotion of vested interests of stakeholders in this business; under the influence of which mass consciousness may form high expectations about the possibilities of 3D printing, thereby likely to cause mass hysteria, regarding the possibility of unlimited span life and as a result - worsening the material prosperity of people.

Influence of 3D printing in transplantation on the development of medicine

One of the problems of modern transplantation is the chronic deficit of organs and biomaterials for performing the surgery. According to a credible source of information from the National Kidney Foundation (the leading organization in the U.S. dedicated to the awareness, prevention and treatment of kidney disease), on average 13 people die

each day while waiting for a life-saving kidney transplant. (21) Many patients in need of urgent operations do not live up to the point when the suitable organ from human donor becomes available. Furthermore, even when there is a donor, "the median wait time for an individual's first kidney transplant is 3.6 years", as National Kidney Foundation states. (21) It happens because the quality of available donor material does not always meet the required standards and the dilemma appears: to perform an operation with the material of unfit quality or delay the operation for undefined period. Therefore, the result of many surgeries depends on many accidents not amenable for prediction. Furthermore, Dave Gobel, a founder of New Organ (a non-profit charity that is unbiased in its nature) states "there are approximately two million estimated individuals in Europe, North America, and in the British Commonwealth who need replacement organs but don't show up anywhere on waiting lists because they're deemed by the medical establishment to be 'not a transplant candidate' due to reasons such as having or having had cancer, being too old, and other triage-based disqualifiers." (22) By the virtue of 3D-printed materials use in transplantation, the risk of low quality organs and undefined delays in operations will decrease and as a result the overall standard of performed surgeries will increase. For example, the use of stem cells and ones own cells as a parent material for 3D printing may overcome the problem of abruptness of donor organs, meaning that the quality characteristics of produced copy can be purposefully modified in regards to the original. The practical opportunity of identified pathology liquidation and acquisition of absolutely new demanded quality characteristics of separate organs and recipient organisms in general emerges. It can be expected that mass use of 3D printing created products in transplantation at the certain point in time will have the revolutionary effect for the development of healthcare overall. It is possible that the opportunity of curing a whole range of illnesses and conditions that can't be treated today might emerge. Maybe, the use of 3D printing technology in transplantation is a premise for the future progress in adjacent fields of medicine. Organovo already produces 3D mini liver assays that are architecturally and biologically identical to human livers. (22) Potential dangers of mismatch between the original and 3D-printed copy's quality characteristics must be taken into account. This can lead to creation of new pathologies and pleasant conditions for already existing but latent conditions. There is a hypothetic possibility that the humanity will face the problems, which was never heard of before. It is impossible to forecast what consequences of the interruption into the complicated system of the human body, which was formed as a result of durable evolution can bring. Moreover, there is a threat that the possibility of mass transplantation treatments can lead to the loss of professional qualification of some medics turning them into craftsmen of organ replacement. In a way, the motivation to perform detailed diagnosis, determine the cause of illness and carrying out complicated treatments decreases if there is a temptation to solve all the problems by replacing one organ with another. It can be assumed that the wide use of 3D printing to some extent will have a negative impact on the development of alternative treatment methods based on the approaches of traditional medicine. Again, there is not

enough research about negative consequences of 3D bioprinted organs and their transplantation from the experts in this industry. Perhaps, the reason why is because 3D bioprinting is a very new phenomenon and it is very difficult to predict what can happen with mass use of the technology. According to research firm Gartner Inc, 3D bioprinting technology "continues to mature, its ability to build customized human anatomical parts has pervasive appeal in medical device markets especially in economically weak regions where it addresses high demand for medical devices." (23)

3D printing and crime

Organ traffickers around the world, according to Vaseashta, collect an estimated \$50 billion annually. (24) Prof. Dr. Ashok K. Vaseashta has expertise in counter-terrorism and countermeasures Nanotechnology, making a credible claim that in the case of the 3D printing innovative technologies' development success, over time the price of producing synthetic human organ replacements can become so low that the economic base of criminal business based on the existing demand for organs will be destroyed. Perhaps cynically, nowadays criminal business will not be able to compete with the business based on the 3D printing economically due to higher costs. Therefore, getting rid of criminal mediators in this area of medicine, the humanity might break the cycle of ethical contradictions, which encouraged the development of transplantation in previous decades mentioned earlier. However, the situation should not be idealised in regards to the chance of complete eradication of criminal activity in the field of transplantation. It can be assumed that crime will not disappear but will try to adapt to new conditions. Probably, in line with the legal market, the black market of illegal synthetic biomaterials will emerge. Maybe, criminal business will try to compete with legal business by lowering their costs like it happens in other fields of modern economy. Firstly, by minimising their costs on innovative research and development by the means of stealing others ideas and technologies, i.e. by stealing from honest researchers and producers. Secondly, by simplification of reliable technologies to the detriment of their quality at the same time selling low quality products under the guise of famous brands with spotless reputation.

Conclusion

Undoubtedly, the arguments provided in this research can only have any practical sense, if the bold assumption of 3D printing, becoming developed enough to the point, where its wide use and replacement of traditional technologies in various parts of human life, including transplantation, then it will be possible. However, this is by no means a groundless utopia. Ray Kurzvile, one of the world's known futurists who has a talent at predicting where technology is heading, considers that in 5 years, 3D printers will be placed in every hospital and in 15 years, the technology of printing inside of the hospital will be mastered during the 2020s. In addition, it is predicted that 10% of people in the developed world will be wearing 3D printed objects in or on their bodies in just three to four years from now. (25) Thus, we are going to witness an exciting era, yet dangerous at the same time, since every person can potentially use his or her imagination for some radical ideas with the use of the technology. During the analysis of the issue, I expanded my

knowledge in different sides of the issue, including the macroeconomics, moral aspects and so on. In my opinion, an idiom "road to hell is paved with good intentions" gives an idea about the current stage of a 3D bioprinting technology, since its development right now is rapid and without much analysis done for the long-term future. Therefore, to prevent 3D printing from becoming human beings' master and being only our servant, the further research should be done in the 3D bioprinting industry to get better understanding of actual negative consequences that the technology might bring and not only positive sides of it, as Carrie Snow states, "Technology... is a queer thing. It brings you great gifts with one hand, and it stabs you in the back with the other". (26) I am convinced that society should definitely encourage the development of 3D bioprinting of organs and issue, but it should be done in a more rational way, where all negative consequences are taken into account and can be tackled by appropriate policies. (4664 words)

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