The Ethical Dilemmas Epigenetic Editing In Utero Presents to Christians

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Abstract

The development of CRISPR epigenetic editing technology was initially impactful due to its potential for disease treatment. However, despite the potential benefits of epigenetic technology, there exist ethical dilemmas surrounding its use in utero. The review of the ethical dilemmas of epigenetic editing in utero from a Christian perspective showed that research in epigenetic editing is promising, yet fraught with peril. The basic ethical issues of epigenetic editing in utero stem from its inaccuracy, lack of research concerning its effects on offspring, an incomplete understanding of gene interactions, and its connection to eugenics. The ethical concerns particularly relevant to Christians are its use of aborted embryos, basis in human judgment, conflict with imago Dei, and possibility for religious hardships.

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The development of new technologies in the medical world can sometimes raise ethical concerns. One example of this phenomenon is found in the use of clustered regularly interspaced short palindromic repeats (CRISPR) technology to perform in utero epigenetic editing, which produces various ethical concerns due to its potential side effects and biological impacts. Furthermore, these ethical concerns are particularly poignant to Christians in the medical field, or who intend to enter the medical field in the future, who hold biblically-based beliefs. However, many Christians are not properly informed about the ethical ramifications of epigenetic editing in utero. Therefore, Christians who have entered or intend to enter careers in health-oriented professions should understand CRISPR and epigenetic editing, the general ethical dilemmas produced by epigenetic editing in utero, the ethical dilemmas that are more impactful to Christians as a whole, and their duties as a Christian to influence positive change in the scientific community.

Epigenetic Editing and CRISPR

Definition of Epigenetic Editing

In order to understand the ethical dilemmas that epigenetic editing presents, it is necessary to first understand epigenetic editing. Epigenetic editing is the targeting of specific loci on epigenetic enzymes in order to induce changes in the genome by causing changes in the epigenetic landscape (Gjaltema & Rots, 2020). Furthermore, epigenetic editing is different from genetic editing as genetic editing directly changes the DNA of the individual whereas epigenetic editing changes the enzymes that affect the epigenome, which controls which genes are transcribed, and thus expressed, within the genome (Day, 2019; Gjaltema & Rots, 2020). This means that epigenetic editing seeks to cause permanent, large-scale changes in the body via the

domino effect: initial changes in the epigenome, resulting changes in the genome from certain genes being turned on or off, and then widespread change.

Experimentation with epigenetic editing can be performed in three main ways: in vitro, in vivo, and in utero. In vitro editing is experimenting on matter that is no longer connected to its source organism while in a curated environment; an example of this would be experimenting with liver cells in a petri dish (Merriam-Webster, n.d.). In vivo editing is when an experiment is performed within the living body of an organism; an example of this would be editing heart muscle cells within a living organism (Merriam-Webster, n.d.). In utero editing occurs when the organism's epigenome is changed before it is born (Merriam-Webster, n.d.). In utero modifications can affect not only the original organism, but also its offspring as all cells in the body are being modified: both somatic and germline cells (Brokowski & Adli, 2019). Understanding the difference among these three methods is important as in vitro does not affect the body of the original organism and in utero can affect the future generations of the subject.

Definition of CRISPR and CRISPR-Cas9

There are multiple ways to perform epigenetic editing, but one of the most effective and well-known ways is by using CRISPR (Gjaltema & Rots, 2020). CRISPR systems were originally limited to directing gene expression in bacteria but were later developed for use in other organisms, including humans, in the 2010s (Bikard et al., 2013; Qi et al., 2013; Vigouroux & Bikard, 2020). CRISPR systems work by creating CRISPR RNAs, which are short RNA sequences that guide the system to the corresponding sequences of DNA in the genome; these can also be known as guide RNAs (gRNAs). Once the system is bound to the correct sequence of DNA, an enzyme paired with the CRISPR system binds to the DNA and activates or deactivates

a gene by cleaving the DNA to shut off the transcription of the targeted gene ("Questions and answers about CRISPR," 2014).

Of the currently known CRISPR systems, CRISPR-Cas9 is one of the most popular ones and uses the enzyme Cas9 to cleave DNA sequences. CRISPR-Cas9's popularity within the scientific community has stemmed from the fact that it is easily customizable to the needed RNA sequence, does not require pairing with another enzyme to cleave the DNA strands as Cas9 is a cleaving enzyme, can target multiple genes at once, and possesses a well-established database of associated gRNA sequences as it is widely used in research (Alsaigh et al., 2019; Gjaltema & Rots, 2020; "Questions and answers about CRISPR", 2014). Understanding the usefulness of CRISPR-Cas9 is important as it is one of the most commonly used epigenetic editing systems and it is often discussed in conjunction with the epigenetic editing of humans.

Current Epigenetic Research

The Effect of Epigenetic Editing on Mucus Production in Vitro

The advancements within the field of epigenetic editing are wide-reaching, but many experiments are mainly focused on better understanding the effectiveness of epigenetic editing. One such study was focused on determining the efficacy of epigenetic editing by using a CRISPR system on a transcription factor in lung epithelial cells to decrease mucus production (Song et al., 2017). Excess mucus production within the airways is a cause of morbidity and mortality in individuals with chronic inflammatory lung diseases (Page et al., 2021). Therefore, reducing mucus production can enable such individuals to have less severe symptoms and a better quality of life. In this study, the SAM-pointed domain-containing Ets-like factor (SPDEF) was targeted as it is a key transcription factor for mucus regulation since experimental mice lacking this transcription factor showed normal mucus reactions upon exposure to allergens as

opposed to a normal hypersecretion response (Park et al., 2007). Therefore, this study was carried out to determine if the epigenetic silencing of the SPDEF could reduce overall mucus production in human lung epithelial cells. The specific epigenetic editing system used was CRISPR/dCas (Song et al., 2017). CRISPR/dCas is a variant of the CRISPR-Cas9 system and uses a catalytically inactive, dead Cas9 to transport transcriptional effectors to the desired site instead of cleaving the DNA upon arrival like an active Cas9 would do (Kazi et al. 2021). The epigenetic editing in vitro was successful as the SPDEF was successfully suppressed. Many chronic diseases are caused by issues in the expression of one or more genes, so epigenetic editing is currently being investigated to see if it is a potential cure due to its ability to alter genes' functions through influencing the epigenome. Therefore, this study is important as it shows that epigenetic editing in vivo could be a possible future treatment option for individuals with chronic respiratory inflammatory diseases as it decreases mucus production, which could improve mortality rates.

CRISPR-Cas9 Research in Vivo

While there are many studies that show the potential benefits of CRISPR editing, there are also many studies that show its hazards. An experiment used the CRISPR-Cas9 system with various gRNAs and targeted the Pcsk9 gene within two different murine models (Akcakaya et al., 2018). The off-target mutations were detected using the verification of in vivo off-targets (VIVO) method. The study found that CRISPR-Cas9 nucleases can cause numerous off-target mutations (Akcakaya et al., 2018). This study also showed that CRISPR-Cas9 causes off-target mutations regardless of what gRNAs are used, but the number of mutations can be reduced by using gRNAs specifically tailored to the procedure. Additionally, there is no guarantee that the VIVO system used to find off-target mutations is completely accurate. Therefore, the

conclusions that can be drawn from this study are that off-target mutations from epigenetic editing are fairly likely, effort must be put into confirming the validity of off-target mutation identification systems, and extensive testing must be done to confirm that the most ideal gRNA is being used in order to reduce the number of off-target mutations.

FIRE-Cas9 System

The possibility of epigenetic editing to produce unforeseen and unwanted side effects is a reality. Therefore, the emergence of the Fkbp/Frb inducible recruitment for epigenome editing by Cas9 (FIRE-Cas9) system has been particularly impactful (Braun et al., 2017). The FIRE-Cas9 system is different from the CRISPR-Cas9 system as it is able to safely induce and reverse its induced epigenetic modifications and uses dCas9 instead of a normal Cas9 (Braun et al., 2017, Jin & Lim, 2022). The ability of FIRE-Cas9 to safely institute changes and subsequently reverse them was demonstrated in a study focusing on its effectiveness (Braun et al., 2017). The FIRE-Cas9 system could allow for a more thorough study of procedures relating to genetic editing because the induced changes can be reversed if adverse reactions to the modification appear or if the changes are ineffective. Furthermore, since FIRE-Cas9 uses dCas9 instead of Cas9, it could be more applicable to certain edits.

The Chinese CRISPR Study

The most controversial study in recent years concerning epigenetic editing was conducted by a Chinese team that performed in utero epigenetic modification on several embryos in 2018 (Shaw, 2020). The research team attempted to decrease the children's susceptibility to HIV by utilizing the CRISPR-Cas9 system to delete the CCR5 gene while the children were embryos. Double deletion of the CCR5 gene was thought to be able to simulate the CCR5Δ32 variant, which provides protection against HIV (Samson et al., 1996). Throughout the experiment, the

scientists referred to their changes as simulating the genotype of the Northern European as the variant was seen in a small number of Northern Europeans (Samson et al., 1996). A singular change in a genotype is not able to emulate an entire genotype or phenotype, so the proposed changes in utero had no possibility of changing their subjects to the obscure concept of the genotype of Northern Europeans. The experimental embryos resulted in the birth of twins and another child. However, while the first use of epigenetic editing in utero is seemingly a step forward for science, the method in which it was performed was atrocious. The study itself was deemed ethically wrong by the majority of the science community, not entirely because of the study's goal, but also due to the process leading up to the experimentation itself. One of the major questions asked of the researchers in this study was why HIV was selected to be the first CRISPR embryo implantation over other heritable genetic diseases. By choosing HIV as the studied disease, the research became focused on removing a normal gene to improve an otherwise normal embryo instead of using epigenetic editing to correct an existing disease-causing gene in an embryo (Ryder, 2018). Additionally, the research, albeit misguided, could have impacted a wider scope of life-saving medicine.

While there were many problems with the study, four main problems should be highlighted. The first problem was that this experiment was conducted in secrecy without any oversight or outside input. Another problem was that the results were published on the main researcher's website instead of a peer-reviewed journal where the study and results could be examined and approved. The third problem was that the consent and information forms were not comprehensive and even untruthful in some parts. The consent forms did not fully explain the scientific process to the participants, stated the point of the project was to develop an AIDS vaccine when it concerned epigenetic editing, incorrectly stated the children would receive the

genotype of the Northern European, and claimed the study would naturally immunize the children while simultaneously stating that the research team was not liable if the children contracted HIV. The consent forms also detailed that the researchers were not responsible for any off-target mutations which was directly contradictory to the experiment because all off-target mutations would be the result of the CRISPR editing. Any one of the problems in the consent and information forms would have been enough to warrant concern over the ethical validity of the experiment, but the combined multitude of mistakes within the forms created an experiment that was undoubtably wrong. The fourth problem with the experiment was that there was no ethics committee approval, which further emphasized the lack of ethics in the forms and study. The secrecy of the experiment, lack of oversight, incorrect method of publication, faulty consent and information forms, and lack of ethics committee approval were all significant problems with the Chinese CRISPR study.

The results of the study indicated that the CRISPR-Cas9 system failed to delete one of the two CCR5 genes and only partially deleted the other CCR5 gene in one of the epigenetically edited twin girls, possessing the pseudonym Lulu (Ryder, 2018). The second twin, dubbed Nana, has deletions in both CCR5 genes. Unfortunately, Lulu exhibited off-target mutations, and both Lulu and Nana showed mosaicism, which means that the CRISPR-induced DNA alterations were not consistent across all cells (Biesecker & Spinner, 2013; Ryder, 2018). The dangers of epigenetic editing in utero are further reinforced by the fact that the intended epigenetic edits were not obtained and multiple off-target mutations resulted. The results of the off-target mutations and faulty CCR5 genes will have to be observed as the children grow up. Overall, the research was misguided and unethical but bears mention as it is the first of its kind.

Conclusions to be Drawn from the Research Overall

These four studies are valuable as they all emphasize various facets of the process of epigenetic editing. The study of the effects of epigenetic editing by the CRISPR/dCas system on epithelial cells in vitro showed the potential for epigenetic editing in vivo to help solve problems of chronic diseases with further research. The murine study of CRISPR-Cas9 in vivo showed that off-target mutations are a risk when performing epigenetic editing and stressed the importance of pairing the correct gRNAs to match with the intended gene sequence. The FIRE-Cas9 epigenetic editing system provides a possible way to have a lower stakes method of epigenetic editing as the induced changes have so far been reversible. However, this is still a newer process, so the FIRE-Cas9 system needs to be further researched so that it is not used carelessly because of its supposed reversible nature. The failures of the unethical Chinese CRISPR study emphasize that the success of epigenetic editing in utero is by no means guaranteed and further reinforce the risks of off-target mutations and the unforeseen consequences of attempting to modify life without extensive research and oversight. The conclusions drawn from the four studies are that epigenetic editing is a life-changing procedure that comes with many potential risks and benefits.

Key Ethical Dilemmas

No Guarantee of Accuracy

Despite the numerous advancements that have been made, and could potentially be made using epigenetic editing in vivo, ethical dilemmas remain that cause researchers to be hesitant to fully explore the technology. For example, as evidenced by the CRISPR-Cas9 in vivo study and the Chinese CRISPR study, the accuracy of the edits induced by epigenetic editing is not completely guaranteed (Akcakaya et al., 2018; Ryder, 2018; Zischewski et al., 2017). The off-target effects of epigenetic editing in utero and in vivo are a consequence of not being able to

completely guarantee that only the desired gene is affected within the genome. The inability to completely guarantee that epigenetic editing will only affect the intended sequences means that the process is not completely reliable nor able to be standardized. Additionally, even if the epigenetic edits target and affect the right gene, there is no guarantee that the effect will be complete as intended or that all genes will be edited the same way (Brokowski & Adli, 2019; Peng et al., 2016). Mosaicism and lack of perfect gene deactivation were seen in both Lulu and Nana in the Chinese CRISPR study, and the effects of such imperfect and differing deletions remain to be seen (Ryder, 2018).

The consequences of mosaicism within germline cells are more impactful than those in somatic cells due to the nature of division, which means that mosaicism due to a lack of accuracy of epigenetic editing in utero is more serious than that of in vivo edits (Campbell et al., 2015; Godschalk et al., 2020). As stated earlier, mosaicism is when different cells present different genotypes due to mutations, so any mutations that are produced as a result of epigenetic editing will become magnified within the genome as the affected cells divide (Biesecker & Spinner, 2013; Campbell et al., 2015; Ryder, 2018). Therefore, the risk of mutations and cancer due to epigenetic editing in utero is much higher than that of in vivo because in vivo epigenetic editing is impacting a fully-formed organism. Additionally, there is evidence that the body's ability to suppress mutations and repair genome instability is much lower during early development (Campbell et al., 2015; Godschalk et al., 2020; Russel & Russel, 2006; Vanneste et al., 2009). Mosaicism in an organism does not always result in diseases and cancer, but the likelihood that mosaicism will impact an individual's health is much higher when it results from mutations during early development (Godschalk et al., 2020; Vanneste et al., 2009). Additionally, the effects of mosaicism on the human body are more thoroughly studied in adult models than in

infant or in utero models, so the potential side effects of mosaicism due to epigenetic editing in utero are even more unclear than epigenetic editing in vivo (Godschalk et al., 2020). Because there is no guarantee of accuracy of epigenetic editing and the impact of any resulting mosaicism is higher when performed in utero instead of in vivo, it is irresponsible to perform epigenetic editing in utero.

It is unethical to perform procedures on developing humans that have lasting, irreversible consequences on all bodily functions of the individual when there is no evidence that consistent, beneficial results are possible. Some of the effects of off-target epigenetic edits are activation or inactivation of genes necessary to the wellbeing and survival of the edited organism, genome instability leading to widespread apoptosis, and induction of oncogenes resulting in cancer (Manghwar et al., 2020). While epigenetic editing presents a potential cure or way to alleviate chronic and heritable diseases, as seen in the in vitro study concerning mucus production, its implementation in utero is not wise because of the potential for it to be more detrimental to the individual's health than their original chronic disease and because of the possibility of death from dysfunctional genes or oncogenes.

Lack of Research into the Long-Term Effects of Epigenetic Editing

Furthermore, there has been little research into the long-term effects of epigenetic editing in vivo within an individual and on their respective future generations (Brokowski & Adli, 2019; Dupras et al., 2019). There is no guarantee that epigenetic editing will be indefinite within an organism, which means that if its use is approved, then it may have to be performed multiple times in order to continue to have the desired effect. This is a problem as every time CRISPR technology is introduced into the body, the risk of harmful effects increases and there is no guarantee that the CRISPR technology will be equally successful at editing the genome every

time. Additionally, it is unclear if epigenetic edits will cause the edited genes to be passed down to future offspring and what effect the edited genes will have on their genomes (Zeps et al., 2021). The existence of such uncertainty surrounding the long-term effects and benefits of epigenetic editing in vivo make it hard to determine if epigenetic editing is an overall beneficial procedure for both the initial patient and their future offspring. There needs to be significantly more research into how epigenetic editing of both somatic and germline cells affects the future offspring of the originally modified subject before it can become ethically acceptable to modify the epigenome of any human. Until in vivo editing is perfected, there should be no thoughts of in utero editing (Brokowski & Adli, 2019; Dupras et al., 2019).

Gene Interactions Are Not Fully Understood

Another reason that epigenetic editing of humans in utero is currently ethically problematic is that the complex interactions between genes are still not completely understood (Brokowski & Adli, 2019). Therefore, modifying one gene that has been linked to a specific disease or condition could have completely unforeseen side effects because its interactions with other genes are not understood. Furthermore, the gene could have additional roles during embryonic development that have not been discovered or researched. Additionally, how one gene effects the subject's phenotype is not able to be fully tested as in vitro and animal models do not represent the entirety of the interactions between the genes of different bodily systems within a human. There also exists no guarantee that genes interact in the same ways within all individuals, so eliminating the same gene in various individuals could potentially have widely different short- and long-term effects on the health of the individual or manifestation of the condition scientists sought to cure by epigenetic editing. Therefore, extensive in vitro and in vivo epigenetic testing is necessary to grasp the consequences of epigenetic editing in utero on a

genome. This is an ethical dilemma because most epigenetic edits are irreversible and the side-effects of such an invasive procedure could last the individual's entire life or be fatal. Furthermore, the phenotype of an individual is not controlled by one gene or a set of genes as regulatory elements and environmental factors shape the gene expression of an individual (Brokowski & Adli, 2019; Jelenkovic et al., 2016). Since not nearly enough research has been performed in vivo in order to pinpoint a specific gene or group of genes that is responsible for a trait or disease, it is ethically wrong to attempt to epigenetically change developing humans, which have differing gene interactions (Chatterjee et al., 2021).

The Potential for Eugenics and Unequal Opportunities

While epigenetic editing is commonly associated with being used to treat chronic or deadly diseases, many people have considered its potential to create better, more perfect humans (Brokowski & Adli, 2019). The idea of editing embryos to exhibit certain traits over others or different traits than they would originally show could potentially become a situation where eugenics makes a return. Eugenics was based upon the idea that humanity can be improved by only allowing those with desirable traits/genes to reproduce (Brokowski et al., 2015). The implementation of eugenics led to the forced sterilization of individuals, enforced racially discriminatory practices and policies, and implied that all individuals are not equally valuable as they do not all possess the same traits (David et al., 1988). By declaring certain genetic traits as more desirable, other intrinsic traits are deemed undesirable. The implementation of epigenetic editing also presents the opportunity for underserved communities to become further marginalized or targeted in the form of eugenics, as epigenetic editing could be monetarily inhibitive to poorer communities. If only those who are epigenetically edited are deemed

desirable, then those that are unable to receive the same modifications can become viewed as somehow lesser despite no change in inherent value.

As soon as epigenetic editing becomes viewed as a way to enhance individuals as opposed to a way to treat them, it becomes a tool of eugenics instead of medicine. The use of epigenetics to only treat diseases and not modify individuals is the only way to prevent such ideas. It is not inherently wrong to attempt to use epigenetic editing in vivo to cure or treat diseases, as seen in the in vitro study aiming to use epigenetic editing to later decrease the mucus production in individuals with chronic respiratory diseases. However, only using epigenetic editing for the purpose of solving disease has already been seen to be impossible as the Chinese CRISPR study was designed around the idea of enhancement and not restoration to a normal standard. If epigenetic editing in utero is allowed to be introduced into the wider population to preemptively treat disease, instead of treating existing diseases through epigenetic editing in vivo, then the desire to introduce epigenetic editing in order to modify humanity may not be far behind. Therefore, epigenetic editing in utero is ethically concerning as there is no indication that there will be no desire to use epigenetic editing as a tool of selection instead of correction.

Summary of Ethical Dilemmas

There are four main ethical dilemmas of epigenetic editing in utero that are pertinent to Christians and non-Christians alike. First, epigenetic editing is still an imperfect process that is unable to guarantee intended results while also not producing unintentional side effects such as off-target mutations or incomplete activation of expected epigenetic editing technology, which could both result in mosaicism. Second, there is a lack of research into the long-term effects of epigenetic editing on both the changed individuals and the offspring of changed individuals generations later. Potentially helpful changes to the initial individual could be completely

detrimental to their future offspring due to unintended, unforeseen consequences of epigenetic editing. Third, the extensive, unpredictable interactions between genes are not fully understood, so there is a high risk of unforeseen consequences caused by epigenetic editing. Also, because the body's condition is not only influenced by genetic factors, it is hard to standardize a treatment process based upon epigenetic editing. Fourth, changing the traits of an individual necessarily leads to the examining of traits to determine the better trait overall, which can be a matter of opinion or preference and presents an opportunity for eugenics to resurface as people seek to obtain ideal genetic traits. This can also lead to disparities within the population as not every community would be able to have equal access to epigenetic editing due to monetary disparities. As Albert Einstein once said, "I do not believe that a moral philosophy can ever be founded on a scientific basis. … Every attempt to reduce ethics to scientific formulas must fail. Of that I am perfectly convinced" (Einstein, 1930, p. 374). The progression of science needs to be done after the consideration of ethics; what is considered ethically right or wrong cannot be based upon the ever-evolving field of science. Therefore, it is prudent to examine all of the ethical problems within a scientific or medical advancement before progressing in order to assure that wrongdoings are not committed in the name of science.

Ethical Dilemmas Specific to Christians

Use of Aborted Human Embryos

While it is undeniable that there are ethical dilemmas caused by epigenetic editing, there are also ethical dilemmas that are more pressing for Christians. One concern is that research into epigenetic editing can, and often does, involve human embryos that were aborted (Nwigwe, 2019). Using aborted embryos in research enforces the idea that aborting babies is useful as scientific achievements can be made as a result, so Christians should be against research using

aborted fetuses (Boyle, 2004). Psalms 127:3 says, “children are a heritage from the Lord, offspring a reward from him,” and Job 31:15 states “Did not he who made me in the womb make them? Did not the same one form us both within our mothers?” (New International Version, 1973/2011). Supporting any scientific research that is furthered by harming children, which are stated to be a purposeful gift from God, is unbiblical. This issue is especially relevant if epigenetic editing is induced in utero because research with human embryos will then be even more crucial and will be mostly dependent on tissues from aborted fetuses as opposed to other human cell cultures. Using research that has some of its foundation in murder places an ethical burden on Christians.

Humanity Bias, Shortsightedness, and Pride

Another ethical issue with epigenetic editing that is concerning to Christians is that humans are fundamentally changing God’s creations to fit human preferences (Peters, 2018). Humanity has an innate tendency towards sin, both intentional and not, which results in humanity constantly falling short of perfection (Hardin, 2019; New International Version, 1973/2011, Romans 3:23). The act of trying to perfect the human genome by human efforts is contrary to God’s design as it is mirroring the idea that humanity is able to save or redeem itself through human efforts. Humans are not able to eliminate their bias when choosing which trait is desirable, so a trait that might be beneficial to humanity and the individual when viewed in the long-term might be deemed unnecessary or malignant since humans are unable to predict and understand the consequences of their actions. The inability to foretell how the epigenetically modified individual will react to the enacted changes once again highlights the possibility that numerous adverse reactions to the edits could result from a misguided attempt to fix one problem. Additionally, if such technologies were able to be instated to positively modify an

individual, the same technology could be used to negatively modify an individual if the individual carrying out the procedure has bad intentions (Hardin, 2019). The innate sinful nature of humans ensures that epigenetic editing in utero can never be carried out in a completely just manner. Furthermore, by seeking to change what God deemed the pinnacle of creation as it is being formed, scientists are pridefully attempting to elevate themselves to the level of God as He is the one who was forming us according to His plans while in the womb (New International Version, 1973/2011, Genesis 1:31; Psalm 139:13). It is neither humanity's duty nor right to make epigenetic edits in utero (Hardin, 2019; Peters, 2018).

There also exists the prideful idea that a more perfect human could be made by epigenetic editing by either increasing genes that influence desirable traits like a greater than average level of empathy or by inhibiting genes that lead to elevated anger levels (Walker, 2009). The goal of creating a more moral individual is wholly misguided as genes may be able to incline someone to present an attitude of virtue or lifestyle of loving others, but due to the inherent flawed nature of humanity, which is unable to be changed, the natural tendency for individuals will always be to sin. All humans are born sinful, and the ability to modify humans will not improve their innate sinful state since redemption from that can only come through Christ. True acts of virtue are able to be achieved through both a relationship with Christ and faithfulness to God, and they are not a byproduct of good genes. The belief that humanity is able to improve itself through epigenetic editing is misplaced and shows how humans are wrongfully inclined to believe that their methods are the most efficient and acceptable way.

The Issue of Imago Dei

Explaining Imago Dei

Epigenetic editing also presents ethical dilemmas to Christians as it is changing humanity itself, which was made in the image of God (New International Version, 1973/2011, Genesis 1:27; Peters, 2018; Welz, 2011). There are numerous beliefs as to what being in the image of God, who is invisible, means, so it is best to understand some of the common stances on what it means to be set apart from the rest of creation due to being the sole possessors of a visible or invisible attribute that allows humanity to mirror God. There are four main theories on what constitutes being in the image of God: representation model, resemblance model, relational model, and dynamic model (Welz, 2011). The representational model focuses on the idea that humans are small reflections of God on earth, which means they have certain responsibilities, like stewardship and dominion over the earth. The resemblance model is centered around the concept that some part of humanity, whether it is an internal or external attribute, resembles God. The relational model emphasizes that the ability to communicate and have a relationship with God is what causes humanity to be in the image of God and is also what allows an individual to better reflect God as the relationship between God and man is deepened. The dynamic model of imago Dei is formed from the idea that free will and the ability to choose one's own path in life separates humanity from other creation; however, the dynamic model is also based upon the idea that being in the image of God is a goal that humanity must continue to strive for by forgetting oneself and one's own will and surrendering to God's will. While the theories approach defining what it means to be made in the image of God differently, they are all worth considering in order to understand the potential implications of epigenetic editing.

The Representation Model within Epigenetic Editing

All four imago Dei models provide different implications in the case of epigenetic editing, but the most impactful on the discussion is the representation model. The representation model conflicts with epigenetic editing as the pursuit of epigenetic editing in order to change the base of humanity is not one of the responsibilities that was given to humanity. Of the responsibilities given to humanity by God, improving upon humanity was not included. One of the key responsibilities given to man is the command to be stewards of the earth and have dominion over it (New International Version, 1973/2011, Genesis 1:26, 28). In commanding humankind to be over creation, God did not give man the power to change humankind itself, but rather the responsibility to care for His other creations. If the goal of changing humankind to man's preference takes precedence over the command to manage creation, then science has stepped outside of God's design.

The Resemblance Model within Epigenetic Editing

The resemblance model of imago Dei contradicts the use of epigenetic editing. Since the resemblance model is based upon the idea that some part of humanity is intrinsically different from other creations, it is in direct opposition to using epigenetic editing to change humanity. The uniqueness of humanity, a creation, to be able to reflect some part of the creator is why epigenetic editing of animals, plants, and tissue samples is seen as less ethically questionable than epigenetically editing humans. By attempting to change the makeup of mankind, scientists are directly ignoring the sanctity of the position of being made in the image of God according to the resemblance model.

The Relational Model within Epigenetic Editing

If the relational model of imago Dei were true, then it would not be in opposition to epigenetic editing. Unlike the representation or resemblance models of imago Dei, the relational model is not really impacted by changing humanity. Because the relational model is based upon the idea that being made in God's image allows man to communicate with God, the only way epigenetic editing could interfere with the idea of imago Dei within the relational model would be if the off-target mutations or side-effects of epigenetic editing rendered someone unable to communicate or have a relationship with God. This is only possible through death as God is able to comprehend feelings and words without having to hear them directly from the individual (New International Version, 1973/2011, Psalm 139:2-4). So, as long as epigenetic editing does not result in the edited individual's death, it does not impact the relational model of imago Dei. Simultaneously, if epigenetic editing did cause an individual to be brain dead or dead, then it would be a problem of murder and not interfering with the image of God, which is a serious problem for different reasons.

The Dynamic Model within Epigenetic Editing

Upon first examination, the dynamic model of imago Dei may not appear to be in conflict with epigenetic editing. However, epigenetic editing conflicts with the dynamic model because it is not only based upon the idea of free will, but also the utilization of that free will to pursue God. If the dynamic model of imago Dei was only based upon the principle of free will, then epigenetic editing would not be ethically complicated because the act of editing others or oneself was an expression of free will. Nonetheless, the dynamic model also stipulates that the free will is only free within the confines of surrendering to God's will for one's life. Epigenetic editing is directly in opposition to this idea as it seeks to thwart the natural state of an individual's body

and impose another's will on its functions. Therefore, epigenetic editing is not condonable under the dynamic model of imago Dei.

Potential for Morality to be Dictated by Non-Christians

Furthermore, if epigenetic editing becomes an accepted treatment option in the future, then it will most likely be instituted under regulations made by government, scientific, or medical organizations like other medical procedures. If epigenetic editing receives approval and guidelines are put into place by governing bodies, then the answer to the question of the morality of epigenetic editing will be answered by non-Christians. When laws, legislation, or policies are made that are considered biblically wrong, then it puts Christian doctors and health care workers in an unfavorable position (Alsaigh et al., 2019). The future legalization of epigenetic editing could force individuals in medical fields to be put in a situation where they are legally compelled to perform a procedure, but are morally opposed to carrying it out.

Summary of Christian-Specific Ethical Dilemmas

Beyond the general ethical concerns of epigenetic editing, there are multiple ethical dilemmas that epigenetic editing forces Christians to face. First, epigenetic editing research, especially that of in utero editing, is founded upon the use of aborted fetuses. This is contrary to Christian beliefs as abortion is considered murder and the use of aborted fetuses in research could become more accepted because of the numerous studies being performed. Second, humanity is unable to eliminate its innate bias, shortsightedness, and pride. Humans are unable to be completely logical as their sinful nature always forces them to have a bias, often towards the less ethical choice, are unable to predict the long-term effects of epigenetic editing, and are prideful in assuming that they are able to change part of the human body to achieve perfect results. Third, following the representative model of imago Dei, epigenetic editing conflicts with

the responsibilities given to man by God as the desire to modify mankind is contradictory to maintaining creation. Fourth, allowing epigenetic editing to become legalized could unnecessarily force Christian medical professionals to choose between their faith and their jobs. The ethical issues that epigenetic editing forces Christians to face are not insignificant.

Duties of Christians in Light of Epigenetic Editing In Utero

Because of the many ethical dilemmas epigenetic editing in utero presents to Christians, Christians need to be proactive about personally becoming more knowledgeable about the subject. Christians, especially those considering entering the medical or government worlds, need to fully understand what epigenetic editing is, and what the potential risks of it are (Hardin, 2019). Only once the procedure itself and its risks are understood can any conversations about the ethical dilemmas it creates be discussed. Furthermore, Christians need to be well-versed in the ethical dilemmas that epigenetic editing presents to both Christians and non-Christians (Gouw, 2020). If a Christian is trying to convince a non-Christian of the dilemmas that epigenetic editing holds, but can only intelligently discuss those that are more pertinent to Christians, then that individual has not only missed an opportunity to cause change, but has perpetuated the idea that Christians have little interest in the scientific world if it does not align with their religion (Wu, 2021). Conversely, if a Christian is unable to provide the reasons why epigenetic editing in utero is in violation of biblical principles and can only provide the general ethical dilemmas that epigenetic editing possesses while discussing epigenetic editing with another Christian, then the issue may not seem as impactful to the Christian they were trying to convince. However, regardless of if someone is trying to have a discussion of the ethical dilemmas of epigenetic editing with a Christian or a non-Christian, it will only be more

beneficial to them and their audience if they have a full grasp of what exactly epigenetic editing is and the wide array of ethical dilemmas epigenetic editing presents (Gouw, 2020; Wu, 2021).

The need for Christians to become educated about epigenetic editing and its dilemmas is especially apparent for any Christians that intend to work in healthcare or governmental legislature jobs. This is because Christians that are working in medical or governmental capacities are most likely to be in situations where epigenetic editing is discussed and potentially legislated (Hardin, 2019). By being informed, Christians can provide clear reasonings for the ethical dilemmas of epigenetic editing or explain the concept of epigenetic editing itself (Wu, 2021). If Christians in those fields are uneducated, then that can also lead to them inadvertently making decisions that are contrary to biblical standards or potentially missing an opportunity to help endorse legislature and guidelines for scientific advancements that are aligned with biblical principles. Christians need to be well-educated on situations that are ethically challenging so that they do not make a decision in the moment that causes them regret.

Another responsibility of Christians is to be more proactive in starting conversations about ethically challenging issues and pushing for change within the scientific world. Being able to hold a conversation that concerns the ethical dilemmas of epigenetic editing is wonderful, but oftentimes situations can be missed where problems can be actively discussed because they are not willing to initiate a conversation that may be contrary to popular opinion or concerns ethics where their Christian faith will become evident (Haitch, n.d.). Many people, Christians and non-Christians alike, are unaware of the ethical problems that medical research or procedures can have due to an overreliance on secular ethics committees and lack of information (Hardin, 2019). Therefore, when Christians are uncertain or afraid to broach ethically challenging topics, they should take the advice given in Joshua 1:9 and “Be strong and courageous. Do not be afraid; do

not be discouraged, for the Lord your God will be with you wherever you go" (New International Version, 1973/2011, Genesis 1:26, 28).

Conclusion

While in vivo epigenetic editing is a procedure that potentially holds promise for future disease treatment, the fact remains that in utero editing causes numerous ethical concerns. Epigenetic editing affects the body by modifying the enzymes that affect the epigenome, which in turn causes changes in gene activity and transcription. Current research has shown that epigenetic editing shows promise for the treatment of diseases and is able to be done using various methods, but also presents the risk of off-target mutations, which can cause harmful side effects or induce death. The Chinese CRISPR study also demonstrated how obtaining consent for epigenetic editing is crucial and that off-target effects and many uncontrollable consequences result from in utero epigenetic editing. Some of the main general ethical concerns of the utilization of epigenetic editing include a lack of accuracy when making changes to the epigenome, little research into the long-term effects of epigenetic editing on future generations, a lack of comprehensive understanding of the complex interactions between genes or the effect of epigenetic editing on the whole body, and the possibility for communities to become marginalized or targeted in the form of eugenics. In addition to the general ethical concerns of epigenetic editing, there are some dilemmas specific to Christians. Epigenetic research is ethically concerning to Christians because it often uses aborted embryos to perform tests, is based upon the judgement of humans who are biased, shortsighted, and prideful, is potentially in conflict with the idea of imago Dei, and could coerce Christian physicians to align with moral standards decided by secular institutions instead of biblical standards. Due to the numerous ethical concerns epigenetic editing presents, it is the responsibility of Christians, especially those

interested in or actively participating in medical or legislative circles, to be proactive about being well-educated on epigenetic editing itself, be updated on current research within the epigenetic field, be able to accurately explain the ethical dilemmas unique to epigenetic editing in utero that are relevant to Christians and non-Christians alike, and willingly initiate and participate in conversations about the ethical concerns of epigenetic editing in utero. Therefore, because of the various ethical issues surrounding epigenetic editing in utero, it is currently unethical to condone epigenetic editing without restrictions, and further examination from a biblical point of view is necessitated.

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