RESEARCH ARTICLE

Human Germline and Heritable Genome Editing: The Global Policy Landscape

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Abstract

Discussions and debates about the governance of human germline and heritable genome editing should be informed by a clear and accurate understanding of the global policy landscape. This policy survey of 106 countries yields significant new data. A large majority of countries (96 out of 106) surveyed have policy documents—legislation, regulations, guidelines, codes, and international treaties—relevant to the use of genome editing to modify early-stage human embryos, gametes, or their precursor cells. Most of these 96 countries do not have policies that specifically address the use of genetically modified *in vitro* embryos in laboratory research (germline genome editing); of those that do, 23 prohibit this research and 11 explicitly permit it. Seventy-five of the 96 countries prohibit the use of genetically modified *in vitro* embryos to initiate a pregnancy (heritable genome editing). Five of these 75 countries provide exceptions to their prohibitions. No country explicitly permits heritable human genome editing. These data contrast markedly with previously reported findings.

Introduction

Development of the CRISPR genome editing technology in 2012–13^{1,2} intensified the decades-long controversy on the likely social consequences and the ethical permissibility or impermissibility of heritable human genome editing. This is when genetic changes are made to *in vitro* early-stage embryos, gametes (eggs and sperm), or germ cells that are the precursors of gametes; genetically modified embryos are then transferred to a uterus to initiate a pregnancy that results in the birth of a child with a modified genome. If the child reaches reproductive age and reproduces using their own gametes, the descendants would inherit a genetically modified genome.

The controversy grew in breadth and intensity in early 2015 in anticipation of,^{3,4} and in response to, the first reported use of CRISPR technology to genetically modify nonviable human embryos.⁵ Debate escalated in November 2018 following confirmation by the Chinese researcher He Jiankui of the birth of twin girls whose genomes had been edited at the early embryo stage in an attempt to confer resistance to HIV infection.⁶ In December 2019, the Nanshan District People's Court

in Shenzhen, China, found He and two others guilty of violating Article 336 of the Criminal Law of the People's Republic of China, which prohibits engaging in medical activities without a license.^{7,8}

Discussions and debates about the social, ethical, and policy implications of heritable human genome editing go back many decades, often focusing on broad concerns about detrimental societal and/or intergenerational consequences.^{9–11} Currently, the controversy spans academic, professional, and policy circles, including commentaries in scientific and scholarly journals; presentations at professional meetings; and published deliberations of national, regional, and international commissions, committees, and panels. Discussions and debates have also gathered momentum in mainstream news publications and media outlets; social media; civil society venues, including public interest and social justice organizations; patient advocacy groups; community groups; and college, university, and high school classrooms.

A notable feature of these exchanges, especially evident in the news media, is the frequent failure to mention

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existing policies (legislation, regulations, guidelines, codes, and international treaties) that govern research involving human genome editing.¹² When relevant policies are mentioned, even in scholarly literature, the information provided is typically vague or inaccurate.^{13,14}

For example, the September 2020 report on *Heritable Human Genome Editing*¹⁵ produced by the International Commission on the Clinical Use of Human Germline Genome Editing, a body cosponsored by the U.S. National Academy of Medicine, the U.S. National Academy of Sciences, and the Royal Society in the United Kingdom (hereafter International Commission), repeatedly notes that heritable human genome editing is “illegal or otherwise not approved in *many countries*” (emphasis added). However, no information is provided about how many countries or which countries these are.

In addition, both academic and general-audience articles^{16–23} often provide an inaccurate account of the policy landscape by failing to mention that 29 countries have ratified the Council of Europe’s *Convention for the Protection of Human Rights and Dignity of the Human Being with regard to the Application of Biology and Medicine: Convention on Human Rights and Biomedicine* (the Oviedo Convention),^{24,25} which clearly prohibits heritable human genome editing. Article 13 of the Oviedo Convention stipulates: “An intervention seeking to modify the human genome may only be undertaken for preventive, diagnostic or therapeutic purposes and only if its aim is not to introduce any modification in the genome of any descendants.” Ratification of the Convention “legally binds a State to implement the Convention ...subject to valid reservations, understandings and declarations.”^{26(ch. 4)}

In 2008, the Center for Genetics and Society self-published BioPolicyWiki,²⁷ an online nonpeer-reviewed compilation of country-level policies regarding eight practices related to human genetics or assisted reproduction. The compilation showed some 40 nations with laws that directly or indirectly prohibit reproductive germline modification (i.e., heritable human genome editing). Since then, this number has been used (with or without proper attribution) in numerous articles.^{3,28,29} The BioPolicyWiki compilation had significant limitations and flaws. It provided little methodological explanation; its categories were interpretive rather than descriptive; its use of source materials was inconsistent and inadequately referenced; and it was not regularly updated.

In 2014, Araki and Ishii¹⁶ reviewed the legal status of heritable human genome editing and addressed “some ethical and social issues that would be raised when each country considers whether genome editing-mediated germline gene correction for preventive medicine should be permitted.” Their review of 39 countries identified 29 that banned heritable human genome modification (by legisla-

tion or guidelines), and one country—the United States—as having restrictive guidelines. Nine countries were said to have policies that were ambiguous. In 2015 and 2017, Ishii used the same data in related articles.^{17,18}

In 2016, Isasi, Kleiderman, and Knoppers reviewed “a representative sample of 16 countries to provide a global ‘snapshot’ of the spectrum of policy and legislative approaches” to a number of interventions involving modification of the human germline for reproductive purposes.³⁰ They categorized each country as restrictive, intermediate, or permissive, and identified these policy categories as deriving from either legislation or regulatory measures.

These articles, widely cited,^{31,32} have serious limitations. First, none of them mentions the Oviedo Convention, which has the force of law in the nations that have ratified it. This omission is particularly striking in the articles by Araki and Ishii (2014) and Ishii (2015 and 2017), which conclude that 29 countries prohibit heritable human genome editing. A significantly different conclusion would have emerged if countries that have ratified the Convention (which number 29) had been included in the review.

Second, while all of these articles provide references to their source documents in supplementary materials, there are important differences in the choices of documents (or excerpts) deemed relevant, in the interpretations (or paraphrased summaries) of these excerpts, and in the judgments about the (im)permissibility of heritable human genome editing. The articles provide markedly different overall judgments for several key countries, and also contrast with ours (Table 1).

A clear and accurate understanding of the global policy landscape for heritable human genome editing is especially important in light of several recent developments, including the He Jiankui debacle³³; reports of other researchers stating that they intend to conduct clinical experiments aimed at producing genome-edited children³⁴; ongoing debate about the need for a global moratorium^{32,35–37}; growing public and policy-maker interest in, and concerns about, such experiments^{38,39}; recently published policy considerations on human genome editing^{36,40–42}; advances in genome editing in human embryos, which confirm significant safety concerns^{43–46}; the recent report *Heritable Human*

Table 1. Examples of different judgments on the permissibility of heritable human genome editing (for reproduction)

Countries	Isasi, Kleiderman, and Knoppers 2016	Araki and Ishii 2014; 2015; 2017
China	Permissive (regulatory)	Ban (legislation)
Mexico	Permissive (legislation)	Ban (legislation)
The United Kingdom	Intermediate (legislation)	Ban (legislation)
The United States	Intermediate (legislation)	Restrictive (guidelines)

*Genome Editing*¹⁵; and the widely anticipated report by the World Health Organization Expert Advisory Committee on Developing Global Standards for Governance and Oversight of Human Genome Editing (hereafter WHO Committee).⁴⁷

To promote clarity and accuracy, this survey provides an overview of the existing global policy landscape for both heritable genome editing and germline genome editing—two related research practices with differing aims and consequences. Heritable genome editing involves the transfer of genetically modified embryos to a uterus to initiate a pregnancy that would result in the birth of a child with a modified genome. Like heritable genome editing, germline genome editing also involves making genetic modifications to gamete precursor cells, eggs, sperm, or early-stage embryos in the laboratory; unlike heritable human genome editing, any resulting genetically modified embryos are not used for reproduction.

Germline genome editing research can be conducted with aims that include understanding the development of human embryos, the reasons for limited success with *in vitro* fertilization, the mechanisms of DNA repair in the early embryo, and the role played by key genes that specify cell fate.^{15(p. 120)} In some cases, it would not be possible to use the resulting genetically modified embryos for reproduction. It is nonetheless important to note that germline genome editing research advances the project of heritable human genome editing insofar as it helps to refine genome editing technology. Some researchers currently conducting human germline genome editing research, including Shoukhrat Mitalipov⁴⁸ and Denis Rebrikov,⁴⁹ openly acknowledge heritable genome editing as their ultimate aim.

The findings presented here are based on a careful survey and update of existing compilations of policies governing research involving human germline and heritable genome editing, scrutiny of relevant primary source documents, review of relevant secondary literature (scholarly articles, committee reports, compilations of research guidelines, and news accounts), and consultations with subject-matter experts.

Materials and Methods

Inclusion criteria for countries surveyed

With the goal of expanding the number and regional distribution of countries for which policy information on human germline and heritable genome editing is available, we sought potentially relevant policy documents for countries that

- are included in BioPolicyWiki²⁷ or named in peer-reviewed articles on policies regarding the modification of the human germline,^{16–18,30}
- have signed or ratified the Oviedo Convention, and

- are represented in the membership of the International Commission⁵⁰ or the WHO Committee.⁵¹

In addition, we obtained information about other countries during research aimed at identifying relevant policy documents, including from secondary literature and from policy experts. This resulted in the inclusion of data from countries not generally thought to have addressed human genome editing research. A total of 106 countries are included in the survey. This includes 10 countries for which local subject-matter experts confirmed that there were no policy documents with potential relevance to human genome editing—Bahamas, Belize, Botswana, Dominica, Grenada, Haiti, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, and Suriname.

Identifying relevant policy documents and excerpts

Policy documents identified for examination and analysis by the authors and subject-matter experts include the Oviedo Convention; laws enacted by national legislatures or other official law-making bodies; ministerial statements that have the force of law; administrative regulations (as in China); royal decrees (as in Saudi Arabia); and in a few countries, research ethics guidelines and ethics codes. The scope of these documents ranges widely. They address general health care and medical licensure, assisted human reproduction, research ethics guidelines, and ethics codes, as well as civil and criminal codes.

We identified a total of 125 potentially relevant policy documents from 96 countries through online research conducted in two rounds, one between July 2019 and February 2020, and the other between June and August 2020. When policy documents were not in English, we used official English translations when available. When these were not available, unofficial English translations were obtained (sometimes using Google's online translation tool) and whenever possible checked with a native speaker.

For each policy document, we identified excerpts directly or potentially relevant to the (im)permissibility of human germline or heritable genome editing. In the absence of direct references to genome editing, we considered excerpts potentially relevant if they included references to closely related research or practices involving assisted human reproduction, human reproductive tissues, human germ cells, gametes or embryos, human cloning, human embryonic stem cells, or the creation of part human hybrids or chimeras.

In analyzing documents without direct reference to “heritable genome editing,” “germline genome editing,” or terms clearly synonymous with them, references

to research or practices involving germ cells, gametes or embryos, fertilization, pregnancy, human heritability, descendants, or future generations were examined in context to identify potentially relevant excerpts on the (im)permissibility of human germline or heritable genome editing. Because the key term “embryo” is variously defined; because references to conception, fertilization, and initiation of pregnancy might be used imprecisely; and because phrases about genetic modifications that “could be passed on,” “would be passed on,” or “were capable of being passed on” might not always have been translated reliably, interpreting these terms and phrases to determine which activity or activities are being addressed was sometimes very challenging. We paid careful attention to definitions; contextual placement; and indications such as titles of the document, section, or chapter.

Categorizing relevant excerpts

Potentially relevant excerpts of the documents were collated and independently examined by each of the four authors (and by an additional researcher in the initial round of reviews). Textual evidence regarding the (im)permissibility of germline or heritable genome editing was identified and categorized by each reviewer in one of five categories. These data are compiled in the Supplementary Appendix Tables SA1–SA6. The five categories are as follows:

- *Permitted*—this means that the research is permissible provided it is undertaken in accordance with any stipulated requirements. Requirements may specify who must authorize the research, who may conduct the research, the premises where the research may be conducted, the terms of consent, and more. In some cases, the stipulated requirements are such that the permitted research is, in fact, severely restricted.
- *Prohibited*—this means that the policy document explicitly states that this type of research is not allowed.
- *Prohibited with exceptions*—this denotes policy documents where the designation *prohibited* is not categorical. This is the case, for example, where there are exceptions for so-called therapeutic purposes. Because the policy documents first stipulate a prohibition and then introduce exceptions, *prohibited with exceptions* was the most accurate terminology for this categorization.
- *Indeterminate*—this captures policy documents for which it was not possible to determine with

certainty whether the research in question is permitted or prohibited. This includes policy documents that mention human germline or heritable genome editing but are unclear as to their (im)permissibility. In addition, this category was assigned to policy documents that do not mention germline or heritable genome editing, but that might encompass these practices in provisions pertaining to the (im)permissibility of certain aspects of assisted human reproduction; research involving human germ cells, gametes or embryos; or genetic modification.

- *No relevant information* (cell in Supplementary Appendix Tables is left blank)—this captures policy documents that do not explicitly reference human germline or heritable genome editing, and where provisions pertaining to assisted human reproduction or related techniques do not obviously bear on their (im)permissibility. We included this category for several reasons: to make explicit the absence of relevant information about the (im)permissibility of human germline or heritable genome editing in existing policy documents where it might reasonably be expected to appear; to flag policy documents that are sometimes referenced in efforts to interpret the current policy situation (e.g., legislation on human cloning); or to highlight policy documents that might be updated at some future time to include explicit reference to human germline or heritable genome editing.

In assigning potentially relevant excerpts to one of these five categories, we made a concerted effort to stay as close as possible to the overt “face value” meaning of the text and to avoid extrapolating from the text.

Policy documents prohibiting the creation of human embryos for research were not, on this basis alone, categorized as prohibiting human germline or heritable genome editing, because such research might nonetheless be permitted using supernumerary embryos (i.e., embryos originally created for reproductive purposes that had been donated for research) or imported embryos. In these cases, the category *prohibited* was assigned to a document only if other text within the document supported this categorization.

No inferences about the (im)permissibility of human germline or heritable genome editing were made solely on the basis of policies governing related practices such as human embryonic stem cell research or human cloning, unless they explicitly referenced genetic modification.

Independent assessments for each policy document using the five categories above were compared to determine the degree and quality of agreement among the reviewers. Agreements and disagreements were discussed at length to examine the validity of the underlying reasoning. Disagreements were discussed until consensus was achieved.

Once all policy documents were assigned to a category, the overall (im)permissibility of human germline and heritable genome editing in countries with multiple documents was assessed. In some instances, the multiple documents for a country were read together to determine the overall policy situation in that country.

While no countries have policy documents in significant disagreement, some have multiple documents in different categories. In these instances, the most determinate document was taken as authoritative. For example, if a country has one document categorized as *indeterminate* and another as *prohibited* (e.g., Nigeria), the country was categorized as *prohibited*. When the sole categorization applied to a country's relevant document(s) was *indeterminate*, that designation was extended to the country, meaning that it was not possible to ascertain the status of germline or heritable genome editing in that country on the basis of the identified document(s).

Results

One hundred and six countries—a little more than half of the United Nations' 193 member states and two nonmember observer states (the State of Palestine and the Vatican)—are included in this survey. Potentially relevant policy documents were identified for 96 of the 106 countries. These data are organized into six Supplementary Appendix Tables SA1–SA6, one for each of the WHO regions⁵²—Africa, Americas, Eastern Mediterranean, Europe, South-East Asia, and Western Pacific.*

Each row of each Supplementary Appendix Table references one source policy document. Hyperlinks to these documents are included to make the pertinent data widely accessible. Relevant excerpts from the documents are included in almost all instances,[†] with original formatting maintained to the extent possible. Countries in which human germline and heritable genome editing are governed by more than one policy document have multiple rows. These rows are organized by the date that the policy went into force, in chronological order with the most recent first.

A total of 125 unique policy documents are included in the Supplementary Appendix Tables SA1–SA6, at least one per country. Policies that are in effect in multiple countries, such as the Oviedo Convention, are counted only once toward this total. Of the 125 documents, four are in draft form pending approval (in Burkina Faso, China, Ireland, and Lebanon).

Regarding human germline genome editing (not for reproduction), potentially relevant documents yielded no relevant information for 56 of 96 countries. Among these 56 countries are 22 of the 29 countries that have ratified the Oviedo Convention, which prohibits heritable human genome editing but leaves the status of germline genome editing to be determined by each country. Among the remaining 40 countries with relevant information, 23 (58%) prohibit this research—19 prohibit it outright and four prohibit it with potential exceptions. Eleven countries explicitly permit human germline genome editing; and six countries are indeterminate (Tables 2–4 and Fig. 1).

The policy landscape for heritable human genome editing (for reproduction) is quite different from that for germline genome editing. Of the 96 countries with potentially relevant policy documents, 78 have policies governing heritable human genome editing. Of these 78 countries, 75 (96%) prohibit heritable human genome editing. Seventy prohibit it outright and five prohibit it with potential exceptions. None of the 96 countries explicitly permits heritable human genome editing; three countries are designated as indeterminate (Tables 5–7 and Fig. 2).

Four countries (Albania, Bahrain, Belarus, and Croatia) have policy documents that appear to prohibit all research involving human embryos. All four are categorized as prohibiting germline genome editing on the basis of their prohibition of all human embryo research. Bahrain and Belarus are categorized as also prohibiting heritable human genome editing due to this blanket prohibition. Albania and Croatia, however, are categorized as prohibiting heritable human genome editing on the basis of their ratification of the Oviedo Convention.

Three countries (China, the United Kingdom, and the United States), all of which are active participants in global policy discussions about human germline and heritable genome editing, have policy situations that are not fully captured by the five-part categorization scheme.

For China, Article 336 of the criminal law and draft Administrative Regulations governing emerging biotechnologies are included, even though neither bears directly on the (im)permissibility of human germline or heritable genome editing. As noted earlier, Article 336 forms the basis on which He Jiankui was convicted. The draft regulations designate which state authority will make determinations about the (im)permissibility

*These data are accurate as at the time of publication. They will be updated as new information becomes available. The updated Tables can be found at <https://tinyurl.com/HumanGenomeEditingPolicies>

[†]In a few instances, a policy document identified as potentially relevant was later determined to contain no text relevant to the (im)permissibility of human germline or heritable genome editing (e.g., for the Czech Republic). In these cases the "Relevant excerpts" column is blank.

Table 2. Policies on human germline genome editing (not for reproduction)

<i>Region (no. of countries)</i>	<i>Countries that permit</i>	<i>Countries that prohibit</i>	<i>Countries that prohibit with exceptions</i>	<i>Countries that are indeterminate</i>	<i>No relevant information</i>
Africa (13)	2	0	0	2	9
Americas (17)	1 (with private funding in US)	4	2	0	10
Eastern Mediterranean (10)	1	4	0	1	4
Europe (46)	3	10	2	2	29
South-East Asia (2)	2	0	0	0	0
Western Pacific (8)	2	1	0	1	4
Total (96)	11	19	4	6	56

of human germline or heritable genome editing (Supplementary Appendix Table SA6 for the Western Pacific).

For the United Kingdom, the regulations that allow for research involving mitochondrial manipulation—an exception to the prohibition on heritable human genome editing—are included (Supplementary Appendix Table SA4 for Europe).

For the United States, the Further Consolidated Appropriations Act of 2020 is included. This omnibus spending bill contains one provision that restricts federal funding of human embryo research (widely known as the Dickey–Wicker Amendment) and another that prohibits the Food and Drug Administration from considering applications for clinical trials involving heritable human genome editing. Several U.S. states ban specific research activities involving human embryos (e.g., for cloning or for stem cell research). This information is not included (Supplementary Appendix Table SA2 for the Americas).

The anomalous categorizations of these source policy documents did not affect the overall categorization of these countries, as other available documents provided clear indications. In China and the United Kingdom, human germline genome editing is permitted. In China, heritable human genome editing is prohibited by the Ethical Guiding Principles on Human Embryonic Stem Cell Research (2003). In the United Kingdom, heritable human genome editing is prohibited by the Human Fertilisation and Embryology Act (1990 as amended 2008), which stipulates that only a “permitted embryo” can be “place[d] in a woman.” The Act legally defines a “permitted” embryo in such a way as to exclude an embryo with altered nuclear DNA. In the United States, human germline

genome editing is prohibited with the use of federal funding but is not otherwise prohibited. Heritable human genome editing is prohibited by a separate provision of the Further Consolidated Appropriations Act, as noted above.

Discussion

This examination of 106 countries identified potentially relevant policy documents from 96 of them, significantly more than the number of countries previously reviewed (39 countries by Araki and Ishii, and 16 countries by Isasi, Kleiderman, and Knoppers). As such, this survey provides the most comprehensive and up-to-date information about the global policy landscape for human germline and heritable genome editing.

Unlike preceding reviews, this survey includes the Oviedo Convention, thereby giving appropriate weight to that treaty’s often under-acknowledged influence on the European and global policy landscape. Each of the 29

Table 4. Countries displayed by policies on human germline genome editing (not for reproduction)

<i>Category</i>	<i>Countries</i>
11 countries permit	Burundi, China, Congo, India, Iran, Ireland, Japan, Norway, Thailand, the United Kingdom, the United States
19 countries prohibit	Albania, Austria, Bahrain, Belarus, Brazil, Canada, Costa Rica, Croatia, Germany, Greece, Lebanon, Malaysia, Malta, Pakistan, Saudi Arabia, Sweden, Switzerland, Uruguay, Vatican
4 countries prohibit with exceptions	Colombia, Finland, Italy, Panama
6 countries are indeterminate	Burkina Faso, Netherlands, Nigeria, Portugal, Singapore, Tunisia
56 countries have no relevant information	Antigua and Barbuda, Argentina, Armenia, Australia, Barbados, Belgium, Benin, Bosnia and Herzegovina, Bulgaria, Central African Republic, Chile, Cuba, Cyprus, Czech Republic, Denmark, Egypt, Estonia, France, Georgia, Guinea, Guyana, Hungary, Iceland, Israel, Jamaica, Kenya, Latvia, Lithuania, Luxembourg, Mexico, Moldova, Montenegro, Namibia, New Zealand, North Macedonia, Oman, Peru, Poland, Qatar, Romania, Russia, San Marino, Serbia, Slovak Republic, Slovenia, South Africa, South Korea, Spain, Tanzania, Trinidad and Tobago, Turkey, Uganda, Ukraine, United Arab Emirates, Vietnam, Zambia

Table 3. Prohibitions on human germline genome editing (not for reproduction) with exceptions

<i>Region</i>	<i>Country</i>	<i>Exception to prohibition</i>
Americas	Colombia	“aimed at relieving suffering or improving the health of the person and humanity”
Americas	Panama	“elimination or reduction of a genetic defect or serious illness”
Europe	Finland	“for the purpose of curing or preventing a serious hereditary disease”
Europe	Italy	“only therapeutic and diagnostic purposes”

Policies on human germline genome editing (not for reproduction) in 96 countries

FIG. 1. Policies on human germline genome editing (not for reproduction) in 96 countries.

Table 5. Policies on heritable human genome editing (for reproduction)

<i>Region (# of countries)</i>	<i>Countries that permit</i>	<i>Countries that prohibit</i>	<i>Countries that prohibit with exceptions</i>	<i>Countries that are indeterminate</i>	<i>No relevant information</i>
Africa (13)	0	5	0	1	7
Americas (17)	0	8	2	0	7
Eastern Mediterranean (10)	0	8	1	0	1
Europe (46)	0	41	2	1	2
South-East Asia (2)	0	2	0	0	0
Western Pacific (8)	0	6	0	1	1
Total (96)	0	70	5	3	18

Table 6. Prohibitions on heritable human genome editing (for reproduction) with exceptions

<i>Region</i>	<i>Country</i>	<i>Exception to prohibition</i>
Americas	Colombia	“aimed at relieving suffering or improving the health of the person and humanity”
Americas	Panama	“elimination or reduction of a genetic defect or serious illness”
Europe	Belgium	“specific therapeutic purpose”
Europe	Italy	“only therapeutic and diagnostic purposes,”
Eastern Mediterranean	United Arab Emirates	Including “therapeutic genetic modifications”

Table 7. Countries displayed by policies on heritable human genome editing (for reproduction)

<i>Category</i>	<i>Countries</i>
0 countries permit	None
70 countries prohibit	Albania, Argentina, Australia, Austria, Bahrain, Belarus, Benin, Bosnia and Herzegovina, Brazil, Bulgaria, Burundi, Canada, Chile, China, Congo, Costa Rica, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, India, Iran, Ireland, Israel, Japan, Kenya, Latvia, Lebanon, Lithuania, Malaysia, Malta, Mexico, Moldova, Montenegro, Netherlands, New Zealand, Nigeria, North Macedonia, Norway, Oman, Pakistan, Poland, Portugal, Qatar, Romania, Russia, San Marino, Saudi Arabia, Serbia, Slovak Republic, Slovenia, South Korea, Spain, Sweden, Switzerland, Thailand, Tunisia, Turkey, the United Kingdom, the United States, Uruguay, Vatican
5 countries prohibit with exceptions	Belgium, Colombia, Italy, Panama, United Arab Emirates
3 countries are indeterminate	Burkina Faso, Singapore, Ukraine
18 countries have no relevant information	Antigua and Barbuda, Armenia, Barbados, Central African Republic, Cuba, Egypt, Guinea, Guyana, Jamaica, Luxembourg, Namibia, Peru, South Africa, Tanzania, Trinidad and Tobago, Uganda, Vietnam, Zambia

Policies on heritable human genome editing (for reproduction) in 96 countries

FIG. 2. Policies on heritable human genome editing (for reproduction) in 96 countries.

ratifying countries is counted toward the total number of countries that prohibit heritable human genome editing.

Of note, 15 of these 29 countries have additional policy documents affirming this prohibition, while 14 do not have additional prohibitions.[‡] Another six countries (Italy, Luxembourg, the Netherlands, Poland, Sweden, and Ukraine) have signed but not ratified the Convention. Of these six countries, the Netherlands, Poland, and Sweden prohibit heritable human genome editing, and Italy prohibits it with exceptions. In 2017, the Council of Europe's Parliamentary Assembly reaffirmed the Oviedo Convention's prohibition on heritable human genome editing, noting in its Resolution that it was doing so in the face of recommendations to establish frameworks for moving forward with germline interventions in human beings by "numerous scientific and ethical bodies."⁵³

Furthermore, this survey takes into account recent policy developments (updates and additions) and makes granular details of source documents easily accessible to readers in the Supplementary Appendix Tables SA1–SA6. The large number of documents assessed makes clear the complexity of the current policy landscape

and the nontrivial challenges of interpreting available documents outside of their cultural and political context.

The findings demonstrate broad agreement among countries that have enacted policy on heritable human genome editing (see map in Fig. 3). Seventy-eight of the 96 countries with potentially relevant documents have policy on heritable human genome editing. Seventy-five of these 78 (96%) include specific prohibitions on heritable human genome editing. From a purely pragmatic standpoint, these data confirming prevalent agreement suggest that development of international consensus on heritable human genome editing is conceivable.

For germline genome editing, the data are significantly different (Fig. 4). Fewer countries have policies that address germline editing (40 of the 96), meaning that the majority lack governance specific to this research. In some instances, this may be because human embryo research is permitted or prohibited, and there is no perceived need for additional policy explicitly permitting or prohibiting embryo research that involves genome editing. Twenty-three countries explicitly prohibit germline genome editing research; 11 permit it; and six are indeterminate.

In some countries, the absence of relevant policy documents, whether for human germline or heritable genome editing, can be explained by the presence of other authoritative documents. For example, in Muslim countries where Islam is the official religion, attention to

[‡]The 14 countries that have ratified the Oviedo Convention but do not have additional prohibitions are: Bosnia and Herzegovina, Cyprus, Czech Republic, Hungary, Iceland, Latvia, Republic of Moldova, Montenegro, Republic of North Macedonia, Portugal, Romania, San Marino, Slovak Republic, and Turkey.

FIG. 3. Policies on heritable human genome editing (for reproduction).

Islamic law is sometimes explicitly entrenched in legislation. Bahrain's legislation on the use of medical technologies that assist in artificial insemination and fertilization stipulates that techniques must be used "in a manner that does not contradict Islamic law." More generally, understanding the (im)permissibility of human genome editing in Muslim countries requires attention to the Islamic Code of Medical and Health Ethics,⁵⁴ *Sharia* (Islamic canonical law), and *fatwas* (nonbinding advice given by Muslim religious scholars on specific issues).^{55§}

In other countries, the absence of relevant policy documents may be due to a range of other factors, including commercial interests, lobbying by the scientific community or patient groups, and attention to local health and research priorities. For example, in low-income countries

with limited investment in human genetic research (such as countries in the Caribbean), legislating on human germline or heritable genome editing could be seen as onerous and an unwarranted use of policymaking resources given local priorities.

Countries without relevant policy documents are at risk of ethics dumping.⁵⁷ This occurs when researchers move their work abroad to a country with no prohibitions, or a country with prohibitions but with no (or limited) enforcement capacity. Patterns of transnational exploitation have been observed with the marketing of recent biotechnologies such as unproven "stem cell therapies"^{58,59} and human nuclear genome transfer.^{60,61} This unethical practice suggests that countries that have chosen to prohibit human germline or heritable genome editing should proactively address the possibility (likelihood) of their nationals exporting their research elsewhere to evade constraints established in their home jurisdictions.

Limitations and future research directions

Several important issues fall beyond the scope of this article. For example, the effectiveness of existing policies,

[§]In 2013 the International Islamic Fiqh Academy (a prominent transnational institution that specializes in addressing the modern religio-ethical system of Islam) and the Islamic Organization for Medical Sciences approved the "Resolution on Heredity, Genetic Engineering and the Human Genome," according to which: (2) It is not permissible to use the genome in a harmful way or in any way that violates Islamic law. ... (9) It is not permissible to conduct clinical research related to the human genome or any of its applications, especially in the fields of biology, genetics and medicine that violate the provisions of Islamic Sharia or do not respect human rights recognized by Islam.⁵⁶

FIG. 4. Policies on human germline genome editing (not for reproduction).

including the presence or strength of enforcement mechanisms associated with them, is not addressed. Different jurisdictions will vary along these dimensions. Furthermore, this article does not include information about the rationale for existing policy documents, nor does it attempt to interpret the current policy situation in each country surveyed. Such a project would have had to take into account international, regional, and subnational legal contexts; existing case law; and important matters of cultural diversity.⁶²

Reliance on translation in accessing and examining relevant policy documents was a serious challenge for many countries. This may have limited whether and which policy documents were found and may also have affected the accuracy of some assessments. While subject-matter experts were consulted whenever possible, access to these experts was shaped by the research team's professional networks.

This survey suggests several fruitful avenues for future work on the global policy landscape for human genome editing. Further scholarly work could explore the terms of debate and deliberation in various countries, assess

the presence and strength of assent or dissent from the policies adopted, and identify commonalities and differences underlying the policy approaches to human germline and heritable genome editing in varying countries and regions. Richer understanding of these underlying dynamics and frameworks will be valuable in heeding calls for broad and inclusive societal discussions and efforts toward consensus.^{63–66}

Conclusion

In contrast to the notable underreporting of existing policies that explicitly prohibit heritable human genome editing, and to vague statements about the “many countries” that do so, this survey finds that a substantial majority of the countries surveyed that have relevant policy documents (75 of 96) prohibit heritable human genome editing. Almost all of these countries prohibit it outright (70 of 75), with five countries allowing specified exceptions. None of the 96 countries explicitly permits heritable human genome editing. The extent of this policy concurrence is striking and should inform

deliberations by formal and informal policy-oriented groups, including those proposing international recommendations, guidelines, or agreements.

Ongoing and future policy discussions of heritable human genome editing require a solid evidence base that transparently assesses and accurately reflects the existing global policy landscape. Given the high profile, intensity, and stakes of the current social, ethical, and policy debates on heritable human genome editing, it is important to establish a common understanding of existing efforts at governance.

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Supplementary Material

Supplementary Appendix Table SA1 Policy Documents for Africa
Supplementary Appendix Table SA2 Policy Documents for Americas
Supplementary Appendix Table SA3 Policy Documents on Eastern Mediterranean
Supplementary Appendix Table SA4 Policy Documents for Europe
Supplementary Appendix Table SA5 Policy Documents for South-East Asia
Supplementary Appendix Table SA6 Policy Documents for Western Pacific
Updated Tables will be available at <https://tinyurl.com/HumanGenomeEditingPolicies>

References

1. Jinek M, Chylinski K, Fonfara I, et al. A programmable dual-RNA-guided DNA endonuclease in adaptive bacterial immunity. *Science*. 2012;337:816. DOI: 10.1126/science.1225829.
2. Cong L, Ran FA, Cox D, et al. Multiplex genome engineering using CRISPR/Cas systems. *Science*. 2013;339:819. DOI: 10.1126/science.1231143.
3. Lanphier E, Urnov F, Haecker SE, et al. Don't edit the human germ line. *Nature*. 519:410–411. DOI:10.1038/519410a
4. Baltimore D, Berg P, Botchan M, et al. A prudent path forward for genomic engineering and germline gene modification. *Science*. 2015;348:36. DOI: 10.1126/science.aab1028.
5. Liang P, Xu Y, Zhang X, et al. CRISPR/Cas9-mediated gene editing in human triploid zygotes. *Protein Cell*. 2015;6:363–372. DOI: 10.1007/s13238-015-0153-5.
6. He J. About Lulu and Nana: Twin girls born healthy after gene surgery as single-cell embryos. 2018. <https://www.youtube.com/watch?v=th0vnOmFltc> (last accessed September 19, 2020).
7. Huaxia [Editor]. China Focus: three jailed in China's "Gene-Edited Babies" trial. XinhuaNet | English.news.cn. www.xinhuanet.com/english/2019-12/30/c_138667350.htm (last accessed September 19, 2020).
8. Lei R, Qiu R. Chinese bioethicists: He Jiankui's crime is more than illegal medical practice. *Bioethics Forum* 2020. <https://www.thehastingscenter.org/chinese-bioethicists-he-jiankui-s-crime-is-more-than-illegal-medical-practice/> (last accessed September 19, 2020).
9. Sinsheimer RL. Prospects for future scientific developments: ambush or opportunity? *Hastings Center Rep*. 1972;2:4–6. DOI: 10.2307/3561399.
10. Walter L, Palmer JG. The Ethics of Human Gene Therapy. New York: Oxford University Press. 1997.
11. Frankel MS, Chapman AR. Human Inheritable Genetic Modifications: Assessing Scientific, Ethical, Religious and Policy Issues. American

- Association for the Advancement of Science, 2000:i–74. <https://www.aaas.org/sites/default/files/germline.pdf> (last accessed September 30, 2020).
12. Marcon A, Master Z, Ravitsky V, et al. CRISPR in the North American popular press. *Genet Med*. 2019;21:2184–2189. DOI: 10.1038/s41436-019-0482-5.
 13. Morrison M, de Saille S. CRISPR in context: towards a socially responsible debate on embryo editing. *Palgrave Commun*. 2019;5:110. DOI: 10.1057/s41599-019-0319-5.
 14. Kaur A. Could seeking human germline genome editing force journeys of transnational care? *Géneros Multidiscipl J Gender Stud*. 2020;9: 184–209. DOI: 10.17583/generos.2020.5077.
 15. National Academy of Medicine, National Academy of Sciences, The Royal Society. Heritable Human Genome Editing. Washington, DC: The National Academies Press. 2020.
 16. Araki M, Ishii T. International regulatory landscape and integration of corrective genome editing into in vitro fertilization. *Reprod Biol Endocrinol*. 2014;12. DOI: 10.1186/1477-7827-12-108.
 17. Ishii T. Germline genome-editing research and its socioethical implications. *Trends Mol Med*. 2015;21:473–481. DOI: 10.1016/j.molmed.2015.05.006.
 18. Ishii T. Germ line genome editing in clinics: the approaches, objectives and global society. *Brief Funct Genomics*. 2017;16:46–56. DOI: 10.1093/bfpg/elv053.
 19. Mullin E. There still aren't any rules preventing scientists from making gene-edited babies. *OneZero*. 2019. <https://onezero.medium.com/a-year-after-the-crispr-babies-debacle-a-rift-is-growing-among-the-worlds-scientists-48c8ded092bb> (last accessed September 19, 2020).
 20. Kuchler H. Jennifer Doudna, CRISPR scientist, on the ethics of editing humans. *Financial Times*. 2020. <https://www.ft.com/content/6d063e48-4359-11ea-abea-0c7a29cd66fe> (last accessed October 1, 2020).
 21. Daley GQ, Lovell-Badge R, Steffann J. After the storm—a responsible path for genome editing. *N Engl J Med*. 2019;380:897–899. DOI: 10.1056/NEJMp1900504.
 22. Cavaliere G, Devolder K, Giubilini A. Regulating genome editing: For an enlightened democratic governance. *Camb Q Healthc Ethics*. 2019;28:76–88. DOI: 10.1017/S0963180118000403.
 23. Rosemann A, Balen A, Nerlich B, et al. Heritable genome editing in a global context: national and international policy challenges. *Hastings Center Rep*. 2019;49:30–42. DOI: 10.1002/hast.1006.
 24. Council of Europe. Convention for the Protection of Human Rights and Dignity of the Human Being with Regard to the Application of Biology and Medicine: Convention on Human Rights and Biomedicine. Vol ETS No.164. 1999. <https://www.coe.int/en/web/conventions/full-list/-/conventions/treaty/164> (last accessed September 19, 2020).
 25. Council of Europe. Convention for the Protection of Human Rights and Dignity of the Human Being with Regard to the Application of Biology and Medicine: Convention on Human Rights and Biomedicine. 1997. <https://www.coe.int/en/web/conventions/full-list/-/conventions/rms/090000168007cf98> (last accessed September 19, 2020).
 26. Byrnes A, Conte A, Gonnot J-P, et al. From Exclusion to Equality: Realizing the Rights of Persons with Disabilities—Handbook for Parliamentarians on the Convention on the Rights of Persons with Disabilities and its Optional Protocol. United Nations, United Nations Office of the High Commissioner, and Inter-Parliamentary Union. 2007. <http://archive.ipu.org/PDF/publications/disabilities-e.pdf> (last accessed September 19, 2020).
 27. Center for Genetics and Society. BioPolicyWiki. WikiPages. http://biopolicy.wiki.org/index.php?title=Main_Page (last accessed September 19, 2020).
 28. Soni S. Human gene editing: who decides. *The Conversation*. <https://theconversation.com/human-gene-editing-who-decides-the-rules-128434> (last accessed September 19, 2020).
 29. Anonymous. Editing humanity. *The Economist*. 2015. <https://www.economist.com/leaders/2015/08/22/editing-humanity> (last accessed October 1, 2020).
 30. Isasi R, Kleiderman E, Knoppers BM. Editing policy to fit the genome? *Science*. 2016;351:337–339. DOI: 10.1126/science.aad6778.
 31. Ledford H. Where in the world could the first CRISPR baby be born? *Nature*. 2015;526:310–311. DOI: 10.1038/526310a.
 32. Lander E, Baylis F, Zhang F, et al. Adopt a moratorium on heritable genome editing. *Nature*. 2019;567:165–168. DOI: 10.1038/d41586-019-00726-5.
 33. Li J, Walker S, Nie J, et al. Experiments that led to the first gene-edited babies: the ethical failings and the urgent need for better governance. *J Zhejiang Univ Sci B*. 2019;20:32–38. DOI: 10.1631/jzus.B1800624.
 34. Cyranoski D. Russian 'CRISPR-baby' scientist has started editing genes in human eggs with goal of altering deaf gene. *Nature*. 2019;574:465–466. DOI: 10.1038/d41586-019-03018-0.
 35. Adelman B, Albright C, Andrews L, et al. [Organized by American Society of Gene and Cell Therapy]. Scientific leaders call for global moratorium on germline gene editing. 2019. <https://www.asgct.org/global/documents/clinical-germline-gene-editing-letter.aspx> (last accessed September 19, 2020).
 36. Deutscher Ethikrat (German Ethics Council). *Intervening in the Human Germline*. Deutscher Ethikrat; 2019:1–280. <https://bit.ly/31UeLdA> (last accessed October 1, 2020).
 37. Adashi EY, Cohen IG. Heritable genome editing: is a moratorium needed? *JAMA*. 2019;322:104–105. DOI: 10.1001/jama.2019.8977.
 38. WHO. Statement on governance and oversight of human genome editing. World Health Organization. 2019. <https://www.who.int/news-room/detail/26-07-2019-statement-on-governance-and-oversight-of-human-genome-editing> (last accessed September 19, 2020).
 39. Press release: joint statement of ethics councils from France, Germany and the United Kingdom on the ethics of human heritable genome editing. The Nuffield Council on Bioethics. 2020. <https://www.nuffieldbioethics.org/news/press-release-joint-statement-on-the-ethics-of-heritable-human-genome-editing> (last accessed September 19, 2020).
 40. The Royal Society Te Apārangi (New Zealand). The use of gene editing in healthcare: Discussion paper. RoyalSociety.org.NZ; 2017:1–12. <https://royalsociety.org.nz/assets/Uploads/The-use-of-gene-editing-in-healthcare-discussion-paper.pdf> (last accessed October 1, 2020).
 41. National Academies of Sciences, Engineering, and Medicine. Human Genome Editing: Science, Ethics, and Governance. Washington, DC: The National Academies Press. 2017.
 42. Nuffield Council on Bioethics. Genome Editing and Human Reproduction: Social and Ethical Issues. Nuffield Council on Bioethics 2018:i–183. <https://www.nuffieldbioethics.org/publications/genome-editing-and-human-reproduction> (last accessed September 19, 2020).
 43. Liang D, Gutierrez NM, Chen T, et al. Frequent gene conversion in human embryos induced by double strand breaks. *bioRxiv*. 2020. DOI: 10.1101/2020.06.19.162214.
 44. Zuccaro MV, Xu J, Mitchell C, et al. Reading frame restoration at the EYS locus, and allele-specific chromosome removal after Cas9 cleavage in human embryos. *bioRxiv*. 2020. DOI: 10.1101/2020.06.17.149237.
 45. Alanis-Lobato G, Zohren J, McCarthy A, et al. Frequent loss-of-heterozygosity in CRISPR-Cas9-edited early human embryos. *bioRxiv*. 2020. DOI: 10.1101/2020.06.05.135913.
 46. Ledford H. CRISPR gene editing in human embryos wreaks chromosomal mayhem. *Nature*. 2020:17–18. DOI: 10.1038/d41586-020-01906-4.
 47. WHO. Human genome editing: WHO establishing expert panel to develop global standards for governance and oversight of human genome editing. World Health Organization—global health ethics. 2018. <https://www.who.int/ethics/topics/human-genome-editing/en/> (last accessed September 30, 2020).
 48. Rathi A. A highly successful attempt at genetic editing of human embryos has opened the door to eradicating inherited diseases. *Quartz*. 2017. <https://qz.com/1041609/a-highly-successful-attempt-at-genetic-editing-of-human-embryos-has-opened-the-door-to-eradicating-inherited-diseases/> (last accessed September 30, 2020).
 49. Cohen J. Embattled Russian scientist sharpens plans to create gene-edited babies. *Science*. 2019. DOI: 10.1126/science.aaz9337.
 50. International Commission on the Clinical Use of Human Germline Genome Editing. National Academies of Sciences, Engineering, Medicine. 2020. <https://www.nationalacademies.org/our-work/international-commission-on-the-clinical-use-of-human-germline-genome-editing> (last accessed September 19, 2020).
 51. WHO. WHO Expert Advisory Committee on Developing Global Standards for Governance and Oversight of Human Genome Editing. World Health Organization. www.who.int/ethics/topics/human-genome-editing/committee-members/en/ (last accessed September 19, 2020).
 52. WHO. Regional Offices. World Health Organization. <https://www.who.int/about/who-we-are/regional-offices> (last accessed September 19, 2020).

53. Council of Europe Parliamentary Assembly. The Use of New Genetic Technologies in Human Beings. 2017. <https://assembly.coe.int/nw/xml/XRef/Xref-XML2HTML-en.asp?fileid=24228&lang=en> (last accessed October 1, 2020).
54. Regional Committee for the Eastern Mediterranean. Islamic Code of Medical and Health Ethics. World Health Organization. Fifty-second Session. Agenda item 8. EM/RC52/7. 2005. https://applications.emro.who.int/docs/em_rc52_7_en.pdf (last accessed September 19, 2020).
55. Ghaly M. Sharia scholars and modern biomedical advancements: what role for religious ethics in the genomic era? In: *Islamic Ethics and the Genome Question*. (Ghaly M; ed). Vol. 1. Brill. 2019:17–46. www.jstor.org/stable/10.1163/j.ctvbqs7qf.6 (last accessed September 19, 2020).
56. International Islamic Fiqh Academy. Resolution on Heredity, Genetic Engineering and the Human Genome. Resolution 203 (9/21). 2013. www.iifa-aifi.org/2416.html (last accessed September 19, 2019).
57. Schroeder D, Cook J, Hirsch F, et al. (eds). *Ethics Dumping: Case Studies from North-South Research Collaborations*. Cham, Switzerland: Springer Open. 2018.
58. Anonymous. Scientists warn against stem cell medical tourism. *Int Med Travel J*. 2016. <https://www.imtj.com/news/scientists-warn-against-stem-cell-medical-tourism/> (last accessed October 1, 2020).
59. Turner L. Preying on public fears and anxieties in a pandemic: businesses selling unproven and unlicensed “stem cell treatments” for COVID-19. *Cell Stem Cell*. 2020;26:806–810. DOI: 10.1016/j.stem.2020.05.003.
60. Reardon S. Genetic details of controversial “three-parent baby” revealed. *Nature*. 2017;544:17–18. DOI: 10.1038/nature.2017.21761.
61. Palacios-González C, Medina-Arellano M de J. Mitochondrial replacement techniques and Mexico’s rule of law: on the legality of the first maternal spindle transfer case. *J Law Biosci*. 2017;4:50–69. DOI: 10.1093/jlb/lsw065.
62. Boggio A, Romano CP, Almqvist, eds. *Human Germline Genome Modification and the Right to Science: A Comparative Study of National Laws and Policies*. Cambridge, England: Cambridge University Press. 2020.
63. Andorno R, Baylis F, Darnovsky M, et al. Geneva statement on heritable human genome editing: the need for course correction. *Trends Biotechnol*. 2020;38:351–354. DOI: 10.1016/j.tibtech.2019.12.022.
64. Baylis F. *Altered Inheritance: CRISPR and the Ethics of Human Genome Editing*. Cambridge, MA: Harvard University Press. 2019.
65. Baylis F. Human genome editing: Our future belongs to all of us. *Issues Sci Technol* 2019;35:42–44.
66. Dryzek JS, Nicol D, Niemeyer S, et al. Global citizen deliberation on genome editing. *Science*. 2020;369:1435. DOI: 10.1126/science.abb5931.