Is Artificial Blood Marketable? An Investigation of Public Trust in Blood Substitutes

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Abstract

Blood shortages are a global problem due to illness, beliefs, medical procedures, and physical isolation. In previous attempts to create a fluid that replaces or mimics blood, scientists have faced compatibility issues and/or health risks, but these attempts have led to new developments and a promising future in the field of synthetic blood. The aim of this research paper is to evaluate the level of public acceptance toward the use of artificial blood, identify which factors (religion, education, age) affect opinion, and determine how much misinformation influences perception. I designed and administered a survey to evaluate public awareness, ethical perception, and willingness to accept artificial blood in clinical contexts, finding that while baseline familiarity with artificial blood was limited, acceptance increased when artificial blood was a life-saving resource or endorsed by physicians and regulatory bodies. Religion influenced ethical acceptance, particularly regarding elective use. This study indicates that medical innovation only reaches its potential when society understands and adopts it. Strengthening public information and supporting biomedical research will be key to making artificial blood a reliable and accessible alternative for everyone.

Introduction

Blood is an essential nutrient for life. Through it, nutrients and oxygen are transported to our tissues, ensuring the survival and functioning of our bodies. Today, we face a profound blood shortage. According to a study made by the University of Chicago, “Every two seconds, someone in the US needs a blood transfusion due to injury, cancer, or disease.” (Hoenigman. P, 2022). More and more patients need transfusions, and it is unclear whether donations will be able to match this increasing demand. This particularly affects people in rural and inaccessible areas, those in countries or regions with a high prevalence of communicable diseases such as HIV, hepatitis, or malaria—where donating blood is not always safe—cancer patients who require repeated transfusions due to the effects of chemotherapy, and the more than nine million Jehovah's Witnesses who do not accept transfusions for religious reasons. These are just some of the examples that demonstrate the urgency of promoting the development of artificial blood.

Over the past two decades, several attempts have been made to create blood substitutes, but these have been unsuccessful due to adverse effects or limitations for recipients (Hsia & Ma, 2011). Blood is an extremely complex fluid that, due to its composition and the interaction of its components with the body, is difficult to replicate using synthetic alternatives. However, these

attempts have served as a foundation for new developments in pharmaceutical companies and university research, bringing us ever closer to a fluid that is safe and suitable for everyone.

Previous studies have analyzed public opinion on these biofluids, finding that many individuals express skepticism due to potential risks and misinformation (Funk, Kennedy, Podrebarac. 2016). Therefore, this study addresses the need to examine public awareness, ethical perceptions, and acceptance of artificial blood in order to better understand the societal barriers that may influence the successful implementation of future blood substitutes.

An original survey was designed and administered in order to understand people's current perspectives on artificial blood. My findings indicate that while individuals are still skeptical about the project–especially because familiarity and information are limited–they are open to the idea of artificial blood, particularly in lifesaving situations, challenging findings by previous scholars.

Literature Review

Blood transfusions are required for a large variety of medical procedures and medical conditions, but blood shortages are a global problem: “Recent modeling studies suggest that almost 2,000 units of blood per 100,000 people are needed to meet current demands. With severe shortages of blood existing in every country in sub-Saharan Africa, south Asia and Oceania, global transfusion needs to outcompete the available blood supply.” Blood banks are key in meeting the need for blood shortages, especially in "blood deserts," geographical areas where there is no timely and affordable access to blood components in more than 75% of the cases where a transfusion is needed (Tripathi. I, 2024). Nevertheless, running one of these centers involves challenges such as equipment shortages, donor safety, and the workforce involved in handling the blood and logistics (e.g., refrigeration). The expanding gap between blood demand and supply has generated the need for the development of a blood substitute (Tripathi. I, 2024). The main goal in recent years has been to create a fluid that can transport oxygen throughout the body (Chaudhry & Chaudhry, 2022). The health sector faces several threats today. Access to new technologies in developing countries, staff shortages, resource scarcity, and political polarization are just some of the challenges. Scholars have long discussed the possibility of developing artificial blood substitutes, and while several hemoglobin-based and engineered red blood cell products have been developed and tested in preclinical and clinical trials, none have yet achieved consistent FDA approval (Khan et al.). This project, if successful, would benefit millions of people globally (Chaudhry & Chaudhry, 2022).

Some of the most benefited would be: people in rural and inaccessible areas due to conflict or isolation, countries with a high prevalence of communicable diseases such as Human Immunodeficiency Virus, hepatitis, or malaria, cancer patients who require repeated blood

transfusions due to the effects of chemotherapy, people with chronic diseases or autoimmune disorders such as aplastic anemia or chronic hemolytic anemias, those who cannot receive transfusions, and people in religious affiliations who, for personal reasons, do not receive blood transfusions, such as Jehovah's Witnesses.

Beyond these patient populations, significant logistical challenges further limit access to donor blood. Blood received from donors must be handled with high standards of cleanliness and temperature; complications can occur when transporting or storing the blood due to a lack of facilities or technologies, especially in less economically developed countries (Hoenigman. P 2022).

Developing an artificial blood: challenges and recent progress

Human blood is an exceedingly complex fluid; due to its composition and interaction with the different bodily systems, it has taken many years to be able to develop a fluid that can mimic its function. Blood passes through several organs that perform different functions for its proper circulation and concentration. These organs are: lungs, kidneys, different glands, and tracts. The lungs are responsible for gas exchange, allowing oxygen to enter the bloodstream and removing carbon dioxide from it, which balances pH levels in the body and allows the body to carry out its main functions. The kidneys purify the blood by removing dissolved waste products. The gastrointestinal tract delivers food nutrients into the blood, and the endocrine glands secrete hormones into the blood to be transported to the corresponding organs.

Blood levels are determined by factors such as gender, age, and weight. On average, an adult contains 60 ml of blood per kilogram of body weight. Blood allows the body to get rid of waste products, transport oxygen and carbon dioxide, regulate internal temperature, and maintain homeostasis. Part of the complication of developing a blood-like fluid is all blood’s components (American Society of Hematology):

- **Red blood cells:** Red blood cells (RBCs) transport oxygen from the lungs to the body's tissues, and receive carbon dioxide to be transported back to the lungs to be exhaled. RBCs also contain a protein called hemoglobin, which is the vital oxygen-carrying protein; it is also responsible for the red color of red blood cells. RBCs are produced in the bone marrow and have a lifespan of approximately 120 days. This cycle allows for homeostasis and adequate blood levels in the bloodstream.
- **White blood cells:** White blood cells, or WBCs, protect the body from infections and diseases by being part of the immune system.
- **Platelets:** Platelets are responsible for stopping bleeding by forming a plug at the site of a blood vessel injury. Allowing the blood to clot is part of the healing process and homeostasis.

- **Blood plasma**: The major component of blood that acts as a transport medium for blood cells, nutrients, hormones, proteins, and waste products throughout the body. It is essential for maintaining blood pressure and maintaining pH levels in the blood.

Blood is one of the most complex and studied human components (Hoenigman. P, 2022). Due to its complexity, previous attempts to create artificial blood have not been successful, but they have paved a promising path to new discoveries and research. Most existing research focuses on substitutes for red blood cells or hemoglobin to facilitate this oxygen transport. However, there is limited coverage regarding the development of other components of blood such as platelets, white blood cells, and plasma. For a blood analog to exist, it must fulfill eight biological functions mentioned by the National Library of Medicine, which are summarized in the table below (Ray et al., 2024):

Artificial Blood Expectations & Requirements

1. Mimicking cell structure and functional replication.	Because RBCs have a biconcave shape, and immune cells have membrane receptors, fabricating cells would require replicating these structures (including shape and size) to ensure proper functioning just like natural cells, whether it is transporting oxygen or responding to pathogens.
2. Biocompatibility and interaction with biological systems.	This biofluid must be compatible with all blood types so that recipients do not produce antibodies against the chemical and to avoid immune reactions. Moreover, after administration, artificial blood must be able to interact seamlessly with biological systems. This includes tissue distribution, flow, circulation, human cells, concentration, etc.
3. Longevity	The lifespan of RBCs is approximately 120 days. These regeneration mechanisms and lifespan must be replicated to maintain the flow and functionality of natural blood.

4. Regulatory considerations	Compliance with regulatory guidelines is essential in the manufacturing of prototypes to ensure quality and safety. Manufacturers need to conduct preclinical studies to evaluate performance, compatibility, and effects, in addition to the FDA approval process. Adhering to these regulatory requirements is necessary for product approval and commercialization.
5. Manufacturing scalability and cost-effectiveness	Several processes are involved in the manufacturing of this fluid, such as 3D bioprinting, nanomaterial and biomaterial interaction, microfluidics, cell encapsulation, etc. These processes can be costly, and therefore effective models must be generated for their proper application.

Table adapted from Ray et al., (2024)

Blood substitutes, to date, are not a complete replacement for blood, but rather an oxygen carrier, which is the primary function of blood. Efforts to develop a fluid capable of mimicking blood and transporting nutrients and oxygen throughout the body without associated toxicity began decades ago. Even now, none of the synthetic substances submitted to the FDA have been approved for clinical use. However, one type of artificial blood, hemoglobin-based oxygen carriers (HBOCs), has been approved for use in two countries: Russia and South Africa. Hemoglobin-based oxygen carriers (HBOCs) are essentially purified hemoglobin, designed to carry oxygen when transfused into a patient. This hemoglobin comes from old donated human blood, bovine blood, or synthetic manufacturing. This blood is treated and filtered to remove viruses, infectious agents, and blood-type markers, and then the hemoglobin is purified. HBOCs are recognized for being efficient and compatible with Rh factors, but once HBOCs release oxygen, they become unstable and dangerous (Khan et al., 2020).

Human blood vessels use nitric oxide, a colorless gas molecule, to keep vessels open and blood flowing. Deoxygenated hemoglobin in HBOCs scavenges nitric oxide (NO) in the blood vessels, causing them to constrict, resulting in high blood pressure, organ stress, and adverse clinical outcomes. In addition, real red blood cells in the blood contain a molecule called 2,3-DPG, which helps hemoglobin release oxygen to human tissues. When hemoglobin floats freely, outside of cells, it loses this helper molecule. As a consequence, the hemoglobin does

not release oxygen when it should. Other symptoms include stomach problems, flu-like symptoms, kidney toxicity, lack of antioxidant protection, and the production of harmful free radicals.

As a solution, scientists modified this hemoglobin by adding polyethylene glycol, also known as PEG molecules, which encapsulated the oxygen-free hemoglobin to prevent it from "straying" from its intended path—like a blanket covering the hemoglobin. PEGylated hemoglobin was designed to avoid the toxic effects caused by its predecessor. As a consequence, the molecule became larger and more uniform, preventing nitric oxide scavenging, vasoconstriction, and reactivity. PEGylated hemoglobin allows for a controlled release of oxygen, useful after shock or traumatic injuries. Nevertheless, the PEGylated molecules, being more "encased," delayed the oxygen delivery process, making the project unviable in situations where rapid oxygen delivery was necessary. Ultimately, PEG molecules are "slow" in the bloodstream but "fast" at helping ischemic tissue, due to slower diffusion and movement. (Khan et al., 2020). The most notable attempts in recent years to create PEGylated hemoglobin have been made by pharmaceutical and biodevelopment companies such as Sangart (Hemospan) and Prolong Pharmaceuticals (Sanguinate), which are key players, alongside earlier efforts by Enzon (PEG-Hb) focusing on improving oxygen delivery for conditions like sickle cell disease; however, most of these trials faced hurdles with efficacy, safety, or FDA approval, leading to shifts in focus (Hsia & Ma, 2011).

Previous research in regards to artificial blood perception.
Regarding the collection of public opinion data, as yet, few surveys have been conducted regarding public opinion on the issue, with most studies dating back to the 2000s. Pew Research Center conducted a survey in 2016, collecting responses on public opinion on artificial blood. The survey by Pew Research found that only 10% of U.S. adults were very enthusiastic about synthetic blood, whereas 20% were very worried; overall, 63% would refuse implantation in their own bodies, and religious respondents were especially likely to view these technologies as unacceptable, due to its moral interference with nature–illustrating the ethical and information gaps that must be addressed in future research. This survey also showed the lack of information found in society regarding blood substitutes, with 77% of respondents having little to no knowledge on this matter, but the opinions on this survey were mostly negative, demonstrating how even without background knowledge, individuals were predisposed to think negatively about the project. Notably, among those who had background knowledge about synthetic blood, nearly half (48%), said that it is something they would want for themselves (Funk, Kennedy, Podrebarac, 2016).
However, this survey faces important limitations: researchers call the fluid "super-blood" and they give it a focus on enhanced stamina, strength, speed, and ease of performing daily actions. By repeatedly framing artificial blood as a human enhancement, it groups it with technologies intended to “improve” normal human abilities rather than restore health. Current development prioritizes therapeutic use for patients with illness or trauma and aims to alleviate chronic blood

shortages, rather than to create "super-blood" for healthy individuals. Moreover, a large proportion of respondents selected “unsure” or expressed moral ambiguity. However, the survey often interprets these responses as skepticism or opposition rather than as indecision caused by a lack of information. Lastly, there is a lack of qualitative follow-up, because even though some explanations were collected through open-ended questions, the survey design does not allow for deeper exploration of *why* individuals feel uncertain or concerned. As a result, the findings may overestimate public resistance and should be interpreted as reflecting reactions to hypothetical enhancement scenarios, rather than to its intended and life-saving medical applications.

According to another survey conducted in 2006,public acceptance of artificial blood is not automatic, but rather depends on knowledge and understanding, trust in medicine, ethical, cultural, or religious facts, and the skepticism that surrounds the topic (Fleming et al., 2007). Artificial blood has a life saving potential, so scientific success unfortunately is not enough without public trust and a positive social perception toward new biomedical technologies. The authors suggest that improved public education and continued biomedical research are essential for the future development and acceptance of blood substitutes. Further, ethical and social considerations must be integrated into research efforts in order to understand the different perspectives around the globe surrounding what could be a new generation of bio fluids and biomaterials (Fleming et al., 2007).

However, while the survey of Fleming et al. (2007), provides valuable insight into public opinion, we still lack full context for the public’s hesitation to accept artificial blood. It is possible that respondent concerns regarding risks, effectiveness, origin of the blood, or ethics, arose due to unfamiliarity with non-donor blood options; in the tables presented, those concerns were highly interconnected, meaning that as one increased, the others tended to worsen as well. In addition, we know that religion plays a role in British citizens’ medical decisions, and therefore, it is again assumed that religion plays a big role in the perception of new technologies that interact with the body, hence, concerns regarding safety and side effects continue to persist. We still wonder if FDA approval and/or public education and/or doctor recommendations would make people more willing to accept synthetic blood. Is acceptance based on trust of higher entities like the FDA, the government, or hospitals, or rather on personal exposure? It is unclear if the general public is skeptical because they know too much or too little—based on the fact that not many surveys have been conducted, and those outside on the web, are from around the year 2000. It seems most likely that the public’s skepticism is due to a lack of knowledge, but that people would be more willing to accept artificial blood in emergencies, rather than to increase stamina. Future studies should therefore examine baseline awareness of artificial blood and identify the primary sources through which individuals obtain formation about these technologies (Fleming et al., 2007).

These divergent perspectives underscore the need for rigorous, reliable data to build public trust in next-generation blood-substitute projects. The findings from Pew Research Center demonstrate the lack of information and understanding on this topic. While some scholars refer to synthetic blood as a fluid that would enhance human capacity to perform daily activities, in the last decade, the fact that it would be a fluid that would benefit many patients by meeting the need for blood has not been addressed. It seems like many members of the public consider this project "immoral" or reckless due to reasons such as personal beliefs, misinformation, or governmental polarization in the healthcare sector. It was also evident from past surveys that those most inclined to disapprove of this project are individuals with religious affiliations, but thanks to new developments and initiatives, it is worth investigating whether the public would be open to a safe and reliable and safe option for patients will be available in the near future.

Methodology

To understand public awareness, ethical perception, and willingness to accept artificial blood in clinical contexts and hypothetical scenarios, I collected demographic data and opinions based on personal beliefs, knowledge and scenarios. This data was analyzed to evaluate trends by population (e.g., North America vs. Latin America), religious affiliation and perception, and how previously acquired information leads to different opinions. The survey also aimed to explore individuals' willingness regarding the use of artificial blood in medical or emergency procedures, and compare life-saving vs. stamina-building fluids. The questions posed in the survey arose thanks to the work of other scholars who showed people didn't know much about the topic, and that personal beliefs and values shape the way of thinking, especially for new technologies.

The most effective method for obtaining public opinion was a survey, due to the ease of data distribution and storage, which would later be used for analysis in the following section. Furthermore, respondents were more likely to express divergent views due to convenience, anonymity, and the avoidance of response bias and time constraints, thereby allowing for a more authentic expression of personal beliefs. The survey analyzed was completed by adults in various geographical locations, primarily in the United States and Latin America, which provided diverse perspectives on public opinion, as more factors such as age, gender, level of education, and religious affiliation were available.

A survey was conducted with a sample of 50 people ranging from ages 16 to 67, and residing in North and South America and Europe. The survey reached these people through social media, friends, teachers, acquaintances, and communication channels such as referrals. Demographic variables such as geography, religion, age, and gender were used to contextualize responses and identify potential patterns across populations. The survey was exploratory, designed to analyze trends and gather data on the most pressing concerns in society regarding the topic.

One of the first questions in the survey aimed to understand the level of prior knowledge that individuals had on the topic. To avoid biasing respondents' perceptions or response bias—tendency for participants to respond inaccurately or falsely to questions—it was clarified in this question that there was no right or wrong answer regarding prior knowledge. Although this question did not have an absolute answer, it is hypothesized that those with more knowledge are more likely to think positively about the project, due to its benefits and the development it has had in recent decades.
A prime example of this was comparing people's willingness to use artificial blood in situations to enhance stamina versus a medical emergency; these questions were constructed with similar wording and the same response scale (0 to 10). This also allowed for an easier collection and analysis of data. Although this is an exploratory survey, a correlation can be predicted between religious affiliation and negative responses to the project. This is based on previous surveys presented in the literature review like the one conducted by Pew Research, in which this correlation of religion and negative thinking was shown.

For this survey of 50 respondents, informed consent was obtained from each individual, along with the information that they could withdraw from the study at any time. The survey posed no risk to the respondents, and although it did not provide a direct benefit, participants were informed that their data would be used for a study.

Results

Demographic information:
50 participants responded to the survey between December 28th and December 31st, 2025. Seventy six percent of participants were female and 24% were male. The mean age was around 26.7 years, and respondents lived primarily in North, South America, and Europe (76%, 23%, and 2%, respectively). Of the 50 responses, 54% were white, 26% were Hispanic, 18% were Asian, and 2% were Black or African American, and other races. Since one of the factors in the previously presented hypothesis was that religious affiliation also influenced the perception of the project, data on religious affiliations were also collected. Seventy two percent of people reported a religious affiliation, with Catholicism and Christianity being the most common (56% and 31%, respectively).

Knowledge:
Before taking the survey, 54% of people had not heard the term "artificial blood" or had no knowledge of it. Forty percent“had heard the term but knew very little,” and only 6% had a basic understanding. No one reported being "fairly knowledgeable" or having "in-depth knowledge of

the topic." These responses are consistent with other surveys previously conducted by other scholars, in which respondents had little or no information about artificial blood and its progress in society.

In addition to asking how much prior knowledge they had on the topic, respondents were also asked to indicate the source of this information, if applicable, and whether they remembered it. Nearly 59% had no prior knowledge, 25% indicated other sources not specific or that they didn't remember the initial source, and smaller percentages came from medical or science articles, school or university coursework, and social media.

The group of respondents that indicated they had prior knowledge but couldn't cite their source poses interesting questions. Perhaps respondents were impacted by response bias or social desirability bias (specifically, these respondents couldn't cite a source because they in fact had no knowledge, but hadn't wanted to reveal that to the researcher). Similarly, we might wonder about the true knowledge of the 40% of people who reported they "had heard the term but knew very little." Therefore, the number of respondents who were able to accurately answer the question "To your knowledge, does artificial blood currently exist or is it being researched as a medical treatment?" might be a more accurate estimate of the sample's true knowledge of artificial blood. Only 36% correctly identified that it is still being researched, and a full 62% of people said they were not sure.

Comfort with artificial blood:

Comfort with receiving artificial blood was one of the most anticipated aspects of this survey. Previous scholars have shown public skepticism due to a lack of information and potential side effects. Furthermore, because it is a very new technology with several failed attempts, it was not being well received by the public. All of these factors were evaluated in the survey, starting with the most basic question: How comfortable would you be receiving artificial blood, if medically necessary? This comfort was assessed on a scale of 0 to 10, where 0 was not comfortable at all, and 10 was very comfortable. As a result, a mean response of 5.7 was obtained, which is 0.7 points above the midpoint of the survey (5). Additionally, the comfort of watching a loved one receive artificial blood was also assessed using the same scale, and we obtained a mean value of 5.96. This difference was not statistically significant.[1]

A raw analysis of these values indicates that respondents, on average, leaned toward acceptance rather than discomfort. Both mean scores exceeded the midpoint of the scale, suggesting a general tendency toward moderate comfort with the use of artificial blood when medically necessary. Notably, respondents expressed greater comfort when considering its use

[1] When measured with a difference of means test.

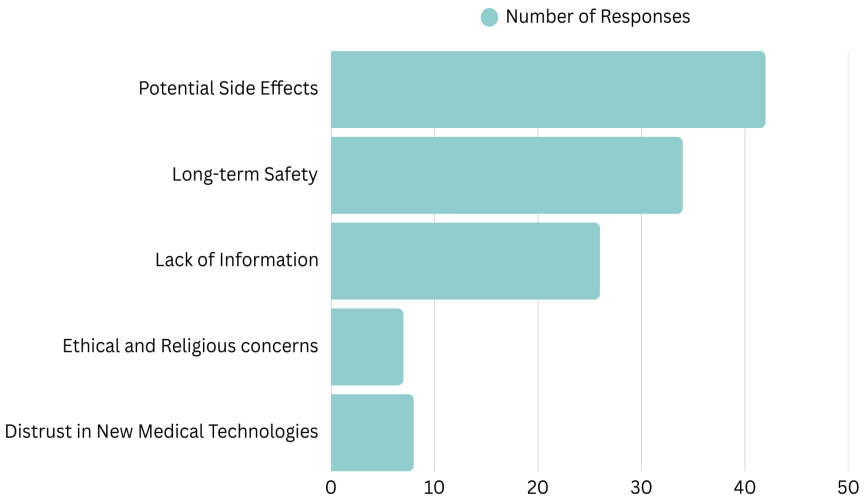
on a loved one than for themselves which may reflect trust in life-saving interventions when framed in an altruistic context.
Although neither value indicates strong enthusiasm, the fact that both means fall above the midpoint suggests that public perception may be shifting away from skepticism documented in earlier studies. Could it be potentially driven by the new treatments that decades ago were seen as irrational? This trend is particularly significant given the historical failures of artificial blood products and the limited public exposure to recent biomedical advances. Rather than outright rejection (like expected), data reflects cautious openness.

To further examine factors influencing comfort in artificial blood, responses to the question "How comfortable would you be receiving artificial blood, if medically necessary?" (question 10) were analyzed based on religious affiliation. Earlier in this study, it was hypothesized that individuals with a religious affiliation would report lower comfort levels toward artificial blood usage than those without religion. This trend has also been documented by previous scholar research, which identified a negative correlation between religious affiliation and acceptance of artificial blood technologies.

When the survey was filtered and analyzed accordingly, the results aligned with this hypothesis. Participants who indicated having a religious affiliation reported an average comfort level of 5.4 on the 10-point scale in response to question 10, whereas participants who reported no religious affiliation demonstrated a higher than average comfort level of 6.3. While both groups reported mean values above the midpoint of the scale, the observed difference suggested that religious affiliation may play a moderate role in comfort with artificial blood like increased caution or reservation. Ethical and/or religious considerations may influence perceptions of emerging medical technologies.

Another point evaluated in this study was participants' primary concerns regarding artificial blood, as well as the factors that would increase their willingness to accept it. Respondents were permitted to select multiple concerns, provide open-ended responses, or indicate the absence of major concerns. The results demonstrated a clear pattern of apprehension centered on uncertainty and insufficient information.

Figure 1: Primary concerns about artificial blood



A substantial majority of participants (85.7%) identified potential side effects as one of their main concerns, making this one the most frequently reported issue. Concerns regarding long-term safety followed closely, with 69% of respondents expressing apprehension about unknown future effects. Notably, 53% of participants cited a lack of information as another significant concern, directly supporting the study's hypothesis that limited public knowledge contributes to negative perceptions of artificial blood.

These findings suggest that skepticism toward artificial blood is rooted in uncertainty surrounding its safety profile and insufficient public understanding. We might think that participants who reported no background knowledge levels expressed more concerns on average than those who had heard the topic or had basic understanding. Interestingly, those with no previous knowledge reported on average 2.38 concerns. In contrast, respondents who had heard the topic reported 2.6 concerns. This specific question then contradicts the previous hypothesis that lack of information would predispose individuals to think more negatively about the project or have more worries. However, this difference was not statistically significant, indicating that the observed variation may be attributed to random chance rather than a meaningful relationship between knowledge level and concern frequency. Therefore, these results suggest that merely having exposure to the topic does not necessarily reduce apprehension, highlighting that the quality and clarity of the information plays a crucial role in shaping public perception and generating trust in new biomedical technologies.

The final question assessed participants' comfort with the widespread use of artificial blood in hospitals in the future. After evaluating more personal levels of interaction–such as individual comfort and comfort with loved ones–this question aimed to examine the outermost sphere of contact: acceptance at a societal level. Responses yielded an average comfort score of 6.18 on the same 0 to 10-point scale used in previous comfort-related questions. While this value does not represent strong enthusiasm it exceeds the average comfort levels reported for more

personal scenarios. This suggests that respondents may feel more at ease with artificial blood when its use is framed within regulated and large-scale medical systems rather than individual contexts. As hospitals are a common-day and trusted space, public trust increased thanks to the confidence posed on hospitals and healthcare professionals. Even though reservations remain, these findings suggest a moderate optimism toward the implementation of artificial blood in the future as the project continues to be studied and then normalized in hospital settings.

Because ethical, moral, and religious values often influence medical decision-making, participants were asked whether they believed the use of artificial blood was morally, ethically, and religiously acceptable. Contrary to findings from previous surveys, 54% of respondents indicated that artificial blood was acceptable, suggesting a greater baseline openness to biomedical innovation than previously reported in the moral field.
However, this apparent acceptance is dimmed by substantial uncertainty. Twenty eight percent of participants indicated that acceptability depended on the situation, while 16% reported being unsure, indicating that for a significant portion of respondents (44%), artificial blood is located in a morally ambiguous space rather than being clearly accepted or rejected. This suggests that ethical acceptance is highly contextual and may depend on factors such as medical necessity, perceived risk, medical endorsement, information provided, among other factors. Interestingly, religious affiliation emerged as a key variable within this ambiguity. Among participants who selected “depends on the conditions” or “unsure,” 82% reported having a religious affiliation, compared to only 18% who did not. This pattern suggests that while religion may not lead to outright rejection, it may contribute to greater ethical and conditional concerns. Taken together, these findings suggest a shift away from religion as a primary barrier to acceptance and toward uncertainty driven by limited information and ethical ambiguity.

Scenarios

One of the most decisive findings when it comes to the scenarios posed in this study, emerged from the question evaluating acceptance of artificial blood in life-threatening circumstances. Participants were asked, “If artificial blood were the only option available to save your life, how likely would you be to accept it?” The question was measured in a scale from strongly reject to strongly accept. Interestingly, no respondent indicated rejection of artificial blood. This result alone demonstrates a near-universal prioritization of survival over hesitancy toward emerging biomedical technologies.

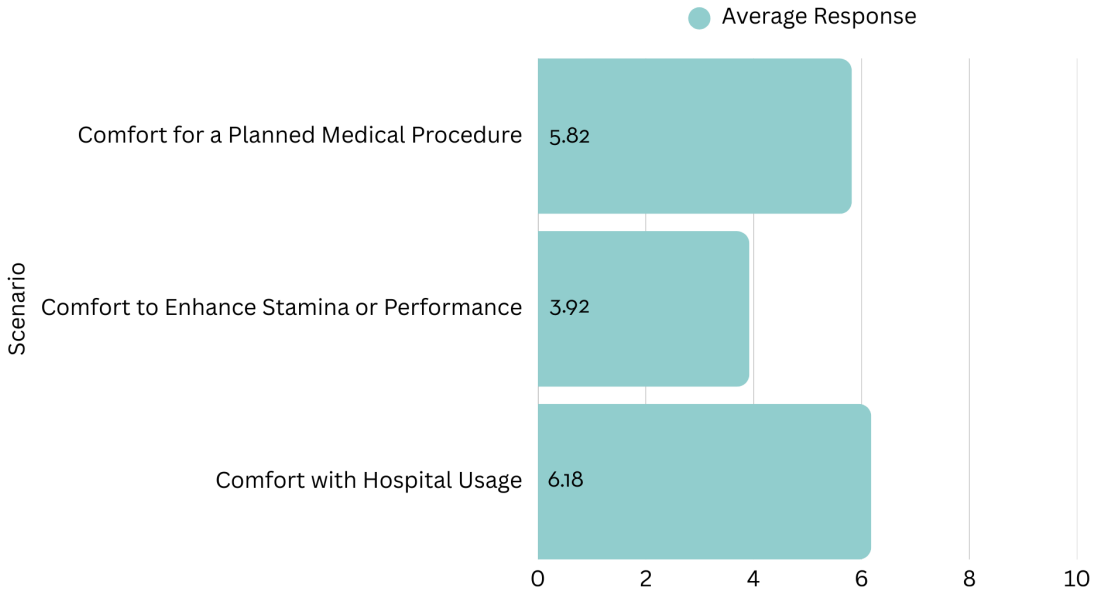
A substantial 73.5% of participants reported that they would “strongly accept” artificial blood. This indicated high confidence in its use when faced with a life-or-death scenario. Additionally, 24.5% indicated “somewhat accept,” suggesting openness to artificial blood despite potential reservations, and only 2% indicated that acceptance in this scenario would “depend on the conditions.” Once again, 0% of respondents selected an answer indicating rejection, underscoring the absence of outright opposition under critical circumstances.

These findings suggest that context plays a crucial role in public acceptance of artificial blood, because while earlier survey questions revealed concerns related to safety or side effects, these concerns appear to vanish when artificial blood is framed as a life-saving option. This supports the interpretation that skepticism toward artificial blood is rooted in uncertainty that can be overridden by medical necessity, as individuals thought about the project as a cost-benefit tool rather than a morally or ethically acceptable resource, and despite all the main concerns. These findings further reported that while baseline familiarity with artificial blood was limited, acceptance increased when artificial blood was a life-saving resource, when more research and testing was carried out, and endorsed by physicians and regulatory bodies like the FDA.

Moving on to two other scenarios presented in the survey, a later scenario sought to analyze willingness to accept artificial blood in everyday contexts such as planned medical procedures (e.g., surgeries), and the scenario that followed explored respondents' perceptions of using artificial blood to enhance physical stamina or performance, as Pew Research had done in previous surveys. To compare the results, both scenarios were measured on a scale of 0 to 10, where 0 represented complete willingness to accept and 10 represented complete willingness to accept.
For scenario 16 (planned medical procedure), the average response was 5.82 on a scale of 10, a score above the median of 5, indicating a slightly stronger acceptance of using artificial blood in a planned medical procedure. On the other hand, for scenario 17 (to facilitate activities of daily life by enhancing stamina), we see a mean response of 3.92 on the same scale, which is 1.08 points below the scale's midpoint of 5, indicating a notable tendency towards rejection of artificial blood to enhance stamina.

Once again, these results support the hypothesis that artificial blood is more likely to be accepted by the public when framed as a biomedical innovation that will help people in serious, even life-saving, situations like surgery. This was a moderate inclination toward acceptance, which we can infer will be stronger if the project undergoes further research in the future and if other factors, such as recommendations from medical professionals or government approval, encourage people to accept artificial blood. On the other hand, we see more prone responses toward rejection when artificial-blood usage to enhance stamina and ease activities of daily life was evaluated. According to these results, individuals are not ready/willing to accept a fluid that will alter their blood composition to enhance their stamina or ease activities of daily life, because it is posed as an option, not a necessity.

Figure 2: Comfort accepting artificial blood across various hypothetical scenarios



Discussion

These findings support the notion that acceptance of emerging biomedical technologies is context-dependent. When artificial blood is framed as a life-saving alternative, individuals are more willing to consider its use despite lingering concerns, regarding safety, ethics, or novelty. Moreover, they highlight the strong potential acceptance of artificial blood in emergency medicine, particularly when no alternatives are available, circling back to those who will be the most benefitted like Jehovah witnesses or those in rural or marginalized areas. This positive inclination underscores the importance of public education and transparent clinical communication in shaping societal acceptance of future blood substitutes.

For this study, the context-dependent nature of acceptance was further confirmed through qualitative insights. In a follow-up conversation with one survey respondent, acceptance of artificial blood to enhance her stamina to help ease the activities of daily life was described as entirely positive due to the presence of a chronic condition, anemia, which limited daily functioning. From their perspective, artificial blood was viewed not only as a medical intervention, but also as a means to counteract physiological effects of her condition to improve quality of life. This evidence emphasizes how personal health circumstances and experiences shape acceptance.

Finally, the open-ended question inviting participants to share additional thoughts yielded no novel concerts or perspectives beyond those captured in the survey. This suggests that the study did not overlook major factors influencing public opinion, and that predefined concepts like safety, side effects, and lack of information, were adequately covered.

Conclusion

This study aimed to examine public knowledge, ethical perceptions, and willingness to accept artificial blood as a medical intervention, particularly in clinical and emergency contexts. Given the persistent global blood shortages and the continued advancement of biomedical research in blood substitute technologies, understanding social acceptance has become increasingly important to ensure that scientific innovation effectively translates into real-world medical practice.

To address this issue, an original survey was designed and administered to assess individuals' knowledge of artificial blood, their ethical and moral perspectives, and their comfort level with its use for themselves, their loved ones, and its general implementation in hospitals—ultimately, evaluating all circles of interaction: personal, familial, and societal. By collecting both quantitative and qualitative responses, this study sought to capture not only levels of acceptance but also the underlying concerns influencing public attitudes.

The results indicate that acceptance of artificial blood is highly context-dependent. While basic knowledge of the topic was limited, participants overwhelmingly expressed a willingness to accept artificial blood when presented as a life-saving option, and no respondent rejected its use in life-or-death situations. Concerns about safety, long-term effects, and a lack of information emerged as the primary barriers to acceptance, confirming the study's hypothesis that insufficient public knowledge plays a significant role in negative perceptions. Furthermore, religious affiliation was associated with lower levels of comfort and greater ethical uncertainty, although many participants expressed conditional acceptance depending on the circumstances. These findings suggest that artificial blood holds great potential for emergency medicine and underserved populations, provided that its clinical introduction is accompanied by transparent communication and public education.

Despite these findings, this study presents several limitations. The sample size and demographic composition may limit the generalizability of the results. Future research could expand upon this work by targeting populations with chronic conditions such as anemia, whose lived experiences may significantly influence perceptions of artificial blood. Comparing the responses of individuals with chronic illnesses to those of generally healthy populations could provide deeper insights into how medical need shapes ethical acceptance and willingness to adopt emerging biomedical technologies.

Overall, this study underscores the importance of integrating scientific advancement with ethical understanding and public trust, reinforcing that the success of artificial blood depends not only on its biomedical efficacy but also on society's willingness to accept it.

Appendix: Draft of Survey Questions

1. Informed Consent
    - I agree to participate
    - I do not agree to participate
2. What is your age?
    - Free response
3. In which region do you currently live?
    - North America
    - South America
    - Europe
    - Africa
    - Asia
    - Middle East
    - Oceania
    - Prefer not to say
4. Do you identify with a religious affiliation?
    - Yes
    - No
    - Prefer not to say

4a. (Optional) If yes, which best describes your affiliation?

- Catholicism
- Christianity
- Judaism
- Islam
- Hinduism
- Buddhism
- Other
- Prefer not to say

5. What is your gender?
    - Male
    - Female
    - Non-binary / gender diverse
    - Prefer not to say
6. How do you identify racially or ethnically?
    - White
    - Hispanic or Latino/a
    - Asian
    - Black or African American

- Other
- Prefer not to say
- Native American or Indigenous
- Middle Eastern or North African

7. Before today, how familiar were you with the concept of artificial blood?
   - I had never heard of it before
   - I had heard the term but knew very little
   - I had a basic understanding
   - I was fairly knowledgeable
8. To your knowledge, does artificial blood currently exist or is it being researched as a medical treatment?
   - Currently offered as a medical treatment
   - Is being researched
   - Not sure
9. If you had any prior knowledge of artificial blood, where did you learn about it? (Select all that apply.)
   - I did not have prior knowledge
   - School or university coursework
   - Medical or science articles
   - Social media
   - News outlets
   - Personal or family medical experiences
   - Religious or ethical discussions
   - Other/I do not remember
10. How comfortable would you be receiving artificial blood, if medically necessary?
    - Scale from 1 to 10, where
      - 0 = Not comfortable at all
      - 10 = Very comfortable
11. How comfortable would you be with a loved one receiving artificial blood, if medically necessary?
    - Scale from 1 to 10, where
      - 0 = Not comfortable at all
      - 10 = Very comfortable
12. Do you believe the use of artificial blood is morally acceptable (ethically or religiously)?
    - Yes
    - No
    - It depends on the situation or conditions
    - Unsure
13. What are your main concerns, if any, regarding artificial blood?
    - Potential side effects

- Long-term safety
- Ethical concerns
- Religious concerns
- Lack of information
- Distrust in new medical technologies
- I have no major concerns
- Other

14. What factors would make you more willing to accept artificial blood? (Meaning comfort receiving a blood substitute)

- Recommendation from a medical professional
- FDA or government approval
- More scientific research and testing
- Personal or family medical experiences
- Religious approval or guidance
- Media coverage or public acceptance
- Nothing would change my opinion

15. If artificial blood were the only option available to save your life, how likely would you be to accept it?

- Strongly accept
- Somewhat accept
- Somewhat reject
- Strongly Reject
- Unsure/Depends on the conditions

16. How willing would you be to accept artificial blood for a planned medical procedure (e.g., surgery)?

- Scale from 1 to 10, where
  - 0 = Not comfortable at all
  - 10 = Very comfortable

17. How willing would you be to accept artificial blood to enhance physical stamina? (Ease activities of daily life)

- Scale from 1 to 10, where
  - 0 = Not comfortable at all
  - 10 = Very comfortable

18. How comfortable would you be with artificial blood being widely used in hospitals in the future?

- Scale from 1 to 10, where
  - 0 = Not comfortable at all
  - 10 = Very comfortable

19. Is there anything else you would like to share about this topic?

- Free response

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