Xenotransplantation

WILEY

Xenotransplantation

ARTICLE OPEN ACCESS

Religion and Attitudes Toward Xenotransplantation: Results of a Nationwide Survey in the United States

Daniel J. Hurst[1] | Luz A. Padilla[2] | Amanda Zink[3] | Brendan Parent[3] | Laura L. Kimberly[3,4]

[1]Department of Family Medicine, Rowan-Virtua School of Osteopathic Medicine, Stratford, New Jersey, USA | [2]Department of Surgery, Division of Cardiothoracic Surgery, University of Alabama at Birmingham, Birmingham, Alabama, USA | [3]Department of Population Health, Division of Medical Ethics, Grossman School of Medicine, New York University, New York, New York, USA | [4]Hansjörg Wyss Department of Plastic Surgery, NYU Grossman School of Medicine, New York, New York, USA

Correspondence: Daniel J. Hurst (hurst@rowan.edu)

Funding: Xenotransplantation ethics research at New York University Grossman School of Medicine is funded by the Applebaum Foundation.

Keywords: attitudes | religion | viewpoints | xenotransplantation

ABSTRACT

Religious viewpoints have been shown to influence the ways in which many persons approach medical decision-making and have been noted as a potential barrier to xenotransplantation acceptance. This study sought to explore how attitudes toward xenotransplantation differ among various religious beliefs. A national Likert-scale survey was conducted in 2023 with a representative sample in the United States. Religious belief was self-reported. Regression analysis was used to identify associations with religious belief and hesitations about xenotransplantation. Five thousand and eight individuals across the United States responded to the survey. The two biggest concerns about xenotransplantation across religious groups were the current lack of evidence about success and the risk of xenozoonosis. Although they still expressed concerns about certain issues, Catholic and Muslim respondents were most comfortable with xenotransplantation for all. On average, the risk of xenozoonosis was a concern among 25% across all religious beliefs (p <0.0001). Orthodox Christians expressed the highest rate of negative feelings toward the recent xenotransplantation experiments on brain dead and living individuals. Those who reported no religion were most likely to have negative feelings about killing pigs for human organ transplant (OR 1.26; 95% CI: 1.08–1.46). As xenotransplantation progresses from pre-clinical studies to clinical trials, and potentially to clinical therapy, hesitations among religious groups exist. Specific studies should be designed to investigate how religious viewpoints can affect xenotransplantation acceptance.

1 | Introduction

Xenotransplantation (XTx) clinical trials appear to be on the horizon. If clinical trials demonstrate XTx to be a safe and effective clinical alternative to allotransplantation, the organ shortage facing the United States (US), as well as the majority of the world, could be alleviated. Recently, XTx has been performed in human decedent models [1–4] and in living human recipients under the US Food and Drug Administration (FDA) expanded access pathway as a precursor to clinical trials [5].

Religious and spiritual viewpoints are one element informing medical decision-making among patients [6–8]. Religion can provide meaning to a person and serve as a manner of coping during illness and times of stress [9, 10]. Religious and spiritual viewpoints are an important factor in how some patients make decisions about new medical treatments, and should be considered in the research about, and approach to, clinical XTx. Disregarding religious considerations could possibly lead to confusion or misinformation, with potential XTx candidates holding viewpoints about XTx that are not in line with the

Abbreviations: FDA, United States Food and Drug Administration; US, United States; XTx, xenotransplantation.

viewpoints of their faith group scholars, or that are based on inaccurate or incomplete information about the treatment.

To date, some studies have assessed the viewpoints of certain groups of people in the US toward XTx, though many of these studies have focused on the views of healthcare providers and patients who have either already received an allotransplant or are on the waitlist for a transplant [11, 12]. Descriptive religious viewpoints toward xenotransplantation have previously been considered by academic scholars within Catholic [13–15], Protestant [16], Jewish [14, 17, 18], Sunni [19, 20], Shia Islam [21], and Hindu [22] faith groups. Limited information about perspectives has been collected from clergypersons in local congregations [23, 24]. The impact of religious beliefs on clergypersons' views toward XTx has been studied previously, though not extensively [23]. Consequently, there is a lack of detailed empirical data illuminating religious perspectives within the general US public. Notably, limited information is available regarding the viewpoints of Orthodox Christianity, Coptic Christianity, The Church of Jesus Christ of Latter-Day Saints (Mormonism), and whether nuances exist among the myriad Protestant denominations [25]. The present study aimed to elucidate attitudes toward XTx among the US population by religious affiliation, and identify attitudes that may be associated with various religious groups that could present barriers to its acceptance.

Identifying and understanding public perceptions of XTx, including concerns that may be religious/spiritual in nature, is crucial for three main reasons. First, it signals that persons are valued holistically and recognizes that religious/spiritual viewpoints are one component of medical decision-making. Second, identifying and understanding religious viewpoints helps to ensure that these important perspectives are incorporated into XTx research and translation into clinical practice as the field progresses. Third, where particular concerns exist, specific interventions to address the concerns may be developed.

2 | Methods

From May 25 to June 14, 2023, a cross-sectional, Likert-scale survey was distributed online in the US through the platform of a private company, Cint (Stockholm, Sweden). Further methodology and details about the company and the implementation of this survey have been reported elsewhere [26]. Demographic characteristics and religious identity were self-reported by respondents.

2.1 | Statistical Analysis

Descriptive statistics were used to summarize demographic characteristics and XTx attitudes by religious belief. Chi-square was used to compare and identify differences between the ten religious affiliation options indicated in the survey tool. Logistic regression was performed to identify characteristics associated with having a negative attitude toward different XTx scenarios and religious identity. A dichotomous outcome for the regression analysis was computed by merging the two negative responses across the Likert-scale into a "non-acceptance" category for the particular question and merging the two positive responses into an "acceptance" category. Given the large survey sample, undecided or neutral responses were dropped in order to avoid erroneously weighing either positive or negative views within the logistic regression analysis. Crude odds ratios and 95% confidence limits are reported for each unfavorable XTx attitude and religious belief model. Studies with similar methodology have been published in the past [26, 27]. In order to weigh the importance of religious beliefs as a primary barrier to XTx, a secondary data analysis was performed to seek an association only among those who cited having religions concerns as their top barrier to XTx and religious identity. Statistical Analytical Software (SAS) 9.4 (SAS institute, Cary, NC) was used for all statistical analysis, and all statistical tests of a two-sided p value of <0.05 were considered significant.

3 | Results

From May to June 2023, 5238 individuals elected to initiate the survey. Of these, 230 declined to participate, resulting in a 95.6% survey completion rate. Demographic information of respondents stratified by religious identity can be found in Table 1. The two largest groups of respondents, by religious tradition, were Christian (Protestant) and Catholic, with 40.4% and 15.8%, respectively. Smaller proportions of persons identifying as Muslim (2.5%), Jewish (2.3%), Mormon (1.0%), Buddhist, Hindu, and Orthodox Christian also responded. Twenty-eight percent of respondents reported having no religion. Seven percent stated their religion as "other." This correlates roughly with the religious makeup of the US found in large surveys, in which approximately 47% were Protestant Christians, 21% Catholic, 1% Muslim, 2% Jewish, 1.6% Mormon, 0.7% Buddhist, 0.7% Hindu, 0.5% Orthodox Christian, and 22.8% being unaffiliated (atheist, agnostic, nothing in particular) [28]. The majority of Muslim respondents were male, while in contrast the majority of Mormon respondents were female. Other religions for the most part had equal gender and age distributions. A high proportion of Buddhist and Hindu respondents reported being of Asian descent while other religions were predominantly of White race (p <0.0001). Over 40% of Jewish and Muslim respondents reported an income higher than 100 000 dollars, while respondents identifying with other religious beliefs were mostly evenly distributed across income categories ($p < 0.0001$). Almost 76.6% of Muslim respondents and 48.9% of Hindu respondents reported following a specific diet ($p < 0.0001$). Notably, 22.6% of Muslim respondents reported being either in need of an organ or currently on the transplant waitlist, but only around 12% of Muslim respondents were registered as living or deceased organ donors. In contrast, among other religious belief groups less than 9% needed an organ or were on the transplant waitlist, and on average 20% were organ donors ($p < 0.0001$).

Likert-scale responses for viewpoints toward XTx scenarios are reported in Table 2. On average only 15% reported being moderately or extremely familiar with XTx among most groups. Mormon and Orthodox Christian respondents were the least familiar with XTx (~8%), while over half of Muslim respondents were familiar ($p < 0.0001$). Orthodox Christian respondents reported the highest rate of experiencing negative feelings after hearing the news of recent experiments in both brain dead (33.3%) and living humans (50%) when compared to any other religious belief group (~25%).

TABLE 1 | Demographic characteristics for survey respondents across the United States by religious belief.

	Christian 2023 (40.4)	Catholic 791 (15.8)	Mormon 48 (1.0)	Orthodox 24 (0.5)	Jewish 114 (2.3)	Muslim 124 (2.5)	Buddhist 81 (1.6)	Hindu 47 (1.0)	None 1407 (28.1)	Other 349 (7.0)	*p* value
Age											<0.0001
18–24	233 (11.5)	58 (7.3)	7 (14.6)	4 (16.7)	11 (9.6)	16 (12.9)	12 (14.8)	9 (19.1)	255 (18.1)	45 (12.9)	
25–34	388 (19.2)	128 (16.2)	5 (10.4)	4 (16.7)	17 (14.9)	36 (29.0)	8 (9.9)	8 (17.0)	352 (25.0)	55 (15.8)	
35–44	419 (20.7)	161 (20.3)	10 (20.8)	3 (12.5)	13 (11.4)	46 (37.1)	10 (12.3)	2 (4.3)	264 (18.8)	75 (27.5)	
45–54	387 (19.1)	169 (21.4)	9 (18.8)	7 (29.2)	20 (17.5)	16 (12.9)	26 (32.1)	14 (29.8)	265 (18.8)	89 (25.5)	
55–64	299 (14.8)	116 (14.7)	7 (14.6)	2 (8.3)	13 (11.4)	8 (6.4)	14 (17.3)	5 (10.6)	138 (9.8)	48 (13.7)	
65 +	297 (14.7)	159 (20.1)	10 (20.8)	4 (16.7)	40 (35.1)	2 (1.6)	11 (13.6)	9 (19.1)	133 (9.4)	37 (10.6)	
Gender											<0.0001
Woman	1088 (53.8)	353 (44.6)	31 (64.6)	9 (37.5)	44 (38.6)	27 (21.8)	38 (46.9)	19 (40.4)	738 (52.4)	201 (57.6)	
Man	925 (45.7)	435 (55.0)	17 (35.4)	14 (58.3)	65 (57.0)	96 (77.4)	42 (51.9)	26 (55.3)	629 (44.7)	133 (38.1)	
Other	10 (0.5)	3 (0.4)	0 (0)	1 (4.2)	5 (4.4)	1 (0.8)	1 (1.2)	2 (4.3)	40 (2.8)	15 (4.3)	
Race/ethnicity											<0.0001
AI/AN/PI/MR	122 (6.0)	27 (3.4)	3 (6.2)	0	7 (6.1)	8 (6.4)	5 (6.2)	2 (4.3)	96 (6.8)	63 (18.1)	
Asian	93 (4.6)	78 (9.9)	4 (8.3)	0	2 (1.7)	24 (19.3)	41 (50.6)	43 (91.5)	141 (10.0)	17 (4.9)	
Black	295 (14.6)	29 (3.7)	5 (10.4)	2 (8.3)	6 (5.3)	10 (8.1)	6 (7.4)	0	135 (9.6)	54 (15.5)	
White	1315 (65.0)	470 (59.4)	30 (62.5)	18 (75.0)	92 (80.7)	72 (58.1)	23 (28.4)	1 (2.1)	897 (63.8)	171 (49.0)	
Hispanic/Latino	198 (9.8)	187 (23.6)	6 (12.5)	4 (16.7)	7 (6.1)	10 (8.1)	6 (7.4)	1 (2.1)	138 (9.8)	44 (12.6)	
Level of education											<0.0001
Some high school/other	133 (6.6)	38 (4.8)	6 (12.5)	0	4 (3.5)	4 (3.2)	6 (7.4)	2 (4.3)	94 (6.7)	34 (9.7)	
High school diploma or equivalent	777 (38.4)	237 (30.0)	14 (29.2)	7 (29.2)	22 (19.3)	24 (19.3)	26 (32.1)	6 (12.8)	625 (44.4)	172 (49.3)	
Associate degree	415 (20.5)	137 (17.3)	9 (18.7)	5 (20.8)	20 (17.5)	7 (5.7)	18 (22.2)	3 (6.4)	237 (16.8)	66 (18.9)	
Bachelor's degree	457 (22.6)	249 (31.5)	14 (29.2)	5 (20.8)	31 (27.2)	44 (35.5)	18 (22.2)	18 (38.3)	332 (23.6)	49 (14.0)	
Graduate degree	241 (11.9)	130 (16.4)	5 (10.4)	7 (29.2)	37 (32.5)	45 (36.3)	13 (16.1)	18 (38.3)	119 (8.5)	28 (8.0)	
Annual household income											<0.0001
<$20 000	283 (14.0)	77 (9.7)	5 (10.4)	1 (4.2)	10 (8.8)	6 (4.8)	10 (12.3)	2 (4.3)	224 (15.9)	80 (22.9)	
$20 000 to $34 999	389 (19.2)	104 (13.1)	10 (20.8)	3 (12.5)	13 (11.4)	14 (11.3)	17 (21.0)	5 (10.6)	254 (18.1)	79 (22.6)	
$35 000 to $49 999	284 (14.0)	113 (14.3)	8 (16.7)	3 (12.5)	16 (14.0)	10 (8.1)	10 (12.3)	13 (27.7)	240 (17.1)	71 (20.3)	
$50 000 to $74 999	401 (19.8)	161 (20.4)	12 (25.0)	10 (41.7)	13 (11.4)	12 (9.7)	17 (21.0)	12 (25.5)	311 (22.1)	63 (18.1)	

(Continues)

TABLE 1 | (Continued)

	Christian 2023 (40.4)	Catholic 791 (15.8)	Mormon 48 (1.0)	Orthodox 24 (0.5)	Jewish 114 (2.3)	Muslim 124 (2.5)	Buddhist 81 (1.6)	Hindu 47 (1.0)	None 1407 (28.1)	Other 349 (7.0)	*p* value
$75 000 to $99 999	292 (14.4)	133 (16.8)	4 (8.3)	2 (8.3)	16 (14.0)	21 (16.9)	10 (12.3)	5 (10.6)	169 (12.0)	24 (6.9)	
>$100 000	374 (18.5)	203 (25.7)	9 (18.8)	5 (20.8)	46 (40.4)	61 (49.2)	17 (21.0)	10 (21.3)	209 (14.8)	32 (9.2)	
Region											<0.0001
Northeast	227 (11.2)	207 (26.2)	2 (4.2)	4 (16.7)	28 (24.6)	58 (46.8)	9 (11.1)	9 (19.1)	225 (16.0)	51 (14.6)	
Midwest	459 (22.7)	154 (19.5)	3 (6.3)	7 (29.2)	15 (13.2)	14 (11.3)	9 (11.1)	8 (17.0)	303 (21.5)	77 (22.1)	
South	952 (47.1)	213 (26.9)	10 (20.8)	6 (25.0)	35 (30.7)	21 (16.9)	26 (32.1)	19 (40.4)	487 (34.6)	132 (37.8)	
West	385 (19.0)	217 (27.4)	33 (68.8)	7 (29.2)	36 (31.6)	31 (25.0)	37 (45.7)	11 (23.4)	392 (27.9)	89 (25.5)	
Diet											<0.0001
No specific diet	1753 (86.7)	661 (83.6)	40 (83.3)	16 (66.7)	83 (72.8)	29 (23.4)	63 (77.8)	24 (51.1)	1242 (88.3)	259 (74.2)	
Vegan/vegetarian/pescatarian/other	270 (13.4)	130 (16.4)	8 (16.7)	8 (33.3)	31 (27.2)	95 (76.6)	18 (22.2)	23 (48.9)	165 (11.7)	90 (25.8)	
Transplant status/experience[a]											
In need of organ or on waitlist	72 (3.6)	28 (3.5)	2 (4.2)	2 (8.3)	5 (4.4)	28 (22.6)	3 (3.7)	2 (4.3)	17 (1.2)	6 (1.7)	<0.0001
I am a transplant recipient	37 (1.8)	20 (2.5)	0	1 (4.2)	3 (2.6)	13 (10.5)	1 (1.2)	0	9 (0.6)	8 (2.3)	<0.0001
I have a chronic disease and might need an organ in the future	122 (6.0)	49 (6.2)	3 (6.2)	2 (8.3)	4 (3.5)	21 (16.9)	3 (3.7)	3 (6.4)	65 (4.6)	25 (7.2)	<0.0001
Someone close to me needs an organ or is on the waitlist	159 (7.9)	47 (5.9)	4 (8.3)	3 (12.5)	6 (5.3)	21 (16.9)	3 (3.7)	3 (6.4)	52 (3.7)	18 (5.2)	<0.0001
Someone close to me got a transplant	213 (10.5)	78 (9.9)	8 (16.7)	2 (8.3)	19 (16.7)	22 (17.7)	8 (9.9)	4 (8.5)	111 (7.9)	25 (7.2)	0.0012
I'm a registered organ donor (after life)	617 (30.5)	223 (28.2)	17 (35.4)	4 (16.7)	24 (21.1)	15 (12.1)	19 (23.5)	8 (17.0)	490 (34.8)	101 (28.9)	<0.0001
I'm registered as a living organ donor or have donated an organ	84 (4.2)	30 (3.8)	2 (4.2)	1 (4.2)	3 (2.6)	16 (12.9)	3 (3.7)	3 (6.4)	58 (4.1)	12 (3.4)	0.0027
I'm a health care professional	131 (6.5)	47 (5.9)	1 (2.1)	3 (12.5)	6 (5.3)	19 (15.3)	2 (2.5)	2 (4.3)	58 (4.1)	17 (4.9)	<0.0001
None of the above	906 (44.8)	392 (49.6)	18 (37.5)	12 (50.0)	60 (52.6)	46 (37.1)	46 (56.8)	29 (61.7)	704 (50.0)	185 (53.0)	0.0004

Abbreviations: AI, American Indian; AN, Alaskan native; MR, more than one race; PI, Pacific Islander.

[a]Subjects were able to select more than one transplant experience of the options below.

TABLE 2 | Attitudes toward xenotransplantation by religious belief.

	Christian 2023 (40.4)	Catholic 791 (15.8)	Mormon 48 (1.0)	Orthodox 24 (0.5)	Jewish 114 (2.3)	Muslim 124 (2.5)	Buddhist 81 (1.6)	Hindu 47 (1.0)	None 1407 (28.1)	Other 349 (7.0)	*p* value
How familiar are you with organ transplants?											<0.0001
Not at all	166 (8.2)	53 (6.7)	8 (16.7)	1 (4.2)	4 (3.5)	7 (5.6)	11 (13.6)	2 (4.3)	123 (8.7)	46 (13.2)	
Slightly	465 (23.0)	188 (23.7)	12 (25.0)	7 (29.2)	30 (26.3)	14 (11.3)	22 (27.2)	7 (14.9)	325 (23.1)	79 (22.6)	
Somewhat	543 (26.8)	184 (23.3)	9 (18.7)	9 (37.5)	30 (26.3)	15 (12.1)	17 (21.0)	16 (34.0)	385 (27.4)	107 (30.7)	
Moderately	483 (23.9)	202 (25.5)	12 (25.0)	6 (25.0)	27 (23.7)	30 (24.2)	22 (27.2)	13 (27.7)	378 (26.9)	69 (19.8)	
Extremely	366 (18.1)	164 (20.7)	7 (14.6)	1 (4.2)	23 (20.2)	58 (46.8)	9 (11.1)	9 (19.1)	196 (13.9)	48 (13.7)	
How familiar are you with xenotransplants?											<0.0001
Not at all	841 (41.6)	292 (36.9)	24 (50.0)	10 (41.7)	43 (37.7)	21 (16.9)	31 (38.3)	18 (38.3)	582 (41.4)	168 (48.1)	
Slightly	464 (22.9)	192 (24.3)	12 (25.0)	6 (25.0)	26 (22.8)	16 (12.9)	21 (25.9)	13 (27.7)	350 (24.9)	82 (23.5)	
Somewhat	350 (17.3)	125 (15.8)	8 (16.7)	6 (25.0)	23 (20.2)	17 (13.7)	12 (14.8)	9 (19.1)	280 (19.9)	50 (14.3)	
Moderately	219 (10.8)	97 (12.3)	2 (4.2)	1 (4.2)	13 (11.4)	33 (26.6)	12 (14.8)	6 (12.8)	126 (8.9)	32 (9.2)	
Extremely	149 (7.4)	85 (10.7)	2 (4.2)	1 (4.2)	9 (7.9)	37 (29.8)	5 (6.2)	1 (2.1)	69 (4.9)	17 (4.9)	
Have you heard the recent news about pig kidneys and hearts being tested in humans who had died?											<0.0001
Yes	812 (40.1)	338 (42.7)	12 (25.0)	9 (37.5)	50 (43.9)	83 (66.9)	36 (44.4)	24 (51.1)	556 (39.5)	130 (37.2)	
No	1211 (59.9)	453 (57.3)	36 (75.0)	15 (62.5)	64 (54.1)	41 (33.1)	45 (55.6)	23 (48.9)	851 (60.5)	219 (62.8)	
If yes, How did you feel when you heard this ($N = 2050$)											<0.0001
All bad	62 (7.6)	22 (6.5)	1 (8.3)	0	5 (10.0)	2 (2.4)	0	2 (8.3)	34 (6.1)	12 (9.2)	
More bad than good	163 (20.1)	61 (18.1)	3 (25.0)	3 (33.3)	5 (10.0)	18 (21.7)	8 (22.2)	4 (16.7)	98 (17.6)	20 (15.4)	
Not bad or good	214 (26.3)	72 (21.3)	3 (25.0)	1 (11.1)	13 (26.0)	4 (4.8)	10 (27.8)	6 (25.0)	173 (31.1)	44 (33.9)	
More good than bad	266 (32.8)	111 (32.8)	4 (33.3)	3 (33.3)	16 (32.0)	25 (30.1)	14 (38.9)	10 (41.7)	187 (33.6)	39 (30.0)	
All good	107 (13.2)	72 (21.3)	1 (8.3)	2 (22.2)	11 (22.0)	34 (41.0)	4 (11.1)	2 (8.3)	64 (11.5)	15 (11.5)	
Have you heard the recent news about a pig heart being transplanted into (put into) a living human?											<0.0001
Yes	887 (43.9)	379 (47.9)	19 (39.6)	10 (41.7)	56 (49.1)	79 (63.7)	37 (45.7)	22 (46.8)	578 (41.1)	131 (37.5)	
No	1136 (56.1)	412 (52.1)	29 (60.4)	14 (58.3)	58 (50.9)	45 (36.3)	44 (54.3)	25 (53.2)	829 (58.9)	218 (62.5)	

(Continues)

TABLE 2 | (Continued)

	Christian 2023 (40.4)	Catholic 791 (15.8)	Mormon 48 (1.0)	Orthodox 24 (0.5)	Jewish 114 (2.3)	Muslim 124 (2.5)	Buddhist 81 (1.6)	Hindu 47 (1.0)	None 1407 (28.1)	Other 349 (7.0)	*p* value
If yes, How did you feel when you heard this ($N = 2198$)											<0.0001
All bad	64 (7.2)	25 (6.6)	1 (5.3)	1 (10.0)	2 (3.6)	5 (6.3)	1 (2.7)	1 (4.6)	32 (5.5)	8 (6.11)	
More bad than good	143 (16.1)	54 (14.2)	4 (21.0)	4 (40.0)	5 (8.9)	15 (19.0)	7 (18.9)	5 (22.7)	77 (13.3)	24 (18.3)	
Not bad or good	233 (26.3)	80 (21.1)	5 (26.3)	1 (10.0)	12 (21.4)	7 (8.9)	6 (16.2)	5 (22.7)	164 (28.4)	38 (29.0)	
More good than bad	323 (36.4)	148 (39.1)	5 (26.3)	2 (20.0)	26 (46.4)	17 (21.5)	16 (43.2)	8 (36.4)	224 (38.8)	45 (34.3)	
All good	124 (14.0)	72 (19.0)	4 (21.1)	2 (20.0)	11 (19.6)	35 (44.3)	7 (18.9)	3 (13.6)	81 (14.0)	16 (12.2)	
How comfortable do you feel about using organs from a pig to help people who need an organ transplant?											<0.0001
Very uncomfortable	247 (12.2)	91 (11.5)	7 (14.6)	4 (16.7)	13 (11.4)	19 (15.3)	11 (13.6)	5 (10.6)	151 (10.7)	48 (13.7)	
Uncomfortable	395 (19.5)	129 (16.3)	6 (12.5)	4 (16.7)	22 (19.3)	20 (16.1)	22 (27.2)	9 (19.2)	269 (19.1)	69 (19.8)	
Neither	587 (29.0)	196 (24.8)	19 (39.6)	5 (20.8)	24 (21.1)	15 (12.1)	21 (25.9)	14 (29.8)	420 (29.9)	120 (34.4)	
Comfortable	562 (27.8)	266 (33.6)	10 (20.8)	7 (29.2)	34 (29.8)	28 (22.6)	21 (25.9)	14 (29.8)	395 (28.1)	82 (23.5)	
Very comfortable	232 (11.5)	109 (13.8)	6 (12.5)	4 (16.7)	21 (18.4)	42 (33.9)	6 (7.4)	5 (10.6)	172 (12.2)	30 (8.6)	
How comfortable would you feel about having a pig organ put into you if you needed an organ transplant?											<0.0001
Very uncomfortable	443 (21.9)	151 (19.1)	12 (25.0)	5 (20.8)	26 (22.8)	33 (26.6)	15 (18.5)	11 (23.4)	300 (21.3)	96 (27.5)	
Somewhat uncomfortable	426 (21.1)	157 (19.8)	12 (25.0)	3 (12.5)	17 (14.9)	13 (10.5)	19 (23.4)	8 (17.0)	275 (19.6)	68 (19.5)	
Neither	347 (17.1)	112 (14.2)	4 (8.3)	2 (8.3)	13 (11.4)	6 (4.8)	17 (21.0)	10 (21.3)	272 (19.3)	70 (20.1)	
Somewhat comfortable	501 (24.8)	231 (29.2)	13 (27.1)	10 (41.7)	41 (36.0)	29 (23.4)	19 (23.5)	12 (25.5)	365 (25.9)	75 (21.5)	
Very comfortable	306 (15.1)	140 (17.7)	7 (14.6)	4 (16.7)	17 (14.9)	43 (34.7)	11 (13.6)	6 (12.8)	195 (13.9)	40 (11.4)	
How comfortable would you feel about having a pig organ put into your child or other loved one if they needed an organ transplant?											<0.0001
Very uncomfortable	487 (24.1)	163 (20.6)	10 (20.8)	6 (25.0)	27 (23.7)	29 (23.4)	19 (23.5)	10 (21.3)	312 (22.2)	106 (30.4)	
Somewhat uncomfortable	409 (20.2)	147 (18.6)	12 (25.0)	3 (12.5)	15 (13.2)	16 (12.9)	18 (22.2)	8 (17.0)	249 (17.7)	63 (18.1)	
Neither	321 (15.9)	110 (13.9)	7 (14.6)	2 (8.3)	19 (16.7)	8 (6.4)	18 (22.2)	13 (27.7)	300 (21.3)	67 (19.2)	

(Continues)

TABLE 2 | (Continued)

	Christian 2023 (40.4)	Catholic 791 (15.8)	Mormon 48 (1.0)	Orthodox 24 (0.5)	Jewish 114 (2.3)	Muslim 124 (2.5)	Buddhist 81 (1.6)	Hindu 47 (1.0)	None 1407 (28.1)	Other 349 (7.0)	*p* value
Somewhat comfortable	505 (24.9)	228 (28.8)	11 (22.9)	10 (41.7)	35 (30.7)	35 (28.2)	17 (21.0)	9 (19.1)	368 (26.1)	79 (22.6)	
Very comfortable	301 (14.9)	143 (18.1)	8 (16.7)	3 (12.5)	18 (15.8)	36 (29.0)	9 (11.1)	7 (14.9)	178 (12.7)	34 (9.7)	
Provided excerpt about gen-editing done for pig											
Does knowing this change how you feel about using a pig organ for a human who needs an organ?											<0.0001
Yes–it makes me less comfortable	302 (14.9)	100 (12.6)	9 (18.8)	3 (12.5)	12 (10.5)	38 (30.7)	9 (11.1)	14 (29.8)	149 (10.6)	44 (12.6)	
Yes–it makes me more comfortable	760 (37.6)	337 (42.6)	16 (33.3)	7 (29.2)	40 (35.1)	56 (45.2)	33 (40.7)	14 (29.8)	535 (38.0)	111 (31.8)	
No–it doesn't change how I feel	961 (47.5)	354 (44.8)	23 (47.9)	14 (58.3)	62 (54.4)	30 (24.2)	39 (48.2)	19 (40.4)	723 (51.4)	194 (55.6)	
How do you feel about raising and killing pigs in order to take their organs and put them into humans? Do you feel:											<0.0001
All bad	331 (16.4)	121 (15.3)	8 (16.7)	4 (16.7)	19 (16.7)	24 (19.3)	16 (19.7)	8 (17.0)	238 (16.9)	80 (22.9)	
More bad than good	489 (24.2)	182 (23.0)	13 (27.1)	7 (29.2)	30 (26.3)	21 (16.9)	19 (23.5)	13 (27.7)	368 (26.1)	84 (24.1)	
Not bad or good	523 (25.9)	210 (26.6)	10 (20.8)	8 (33.3)	26 (22.8)	16 (12.9)	23 (28.4)	13 (27.7)	409 (29.1)	105 (30.1)	
More good than bad	465 (23.0)	177 (22.4)	9 (18.8)	3 (12.5)	22 (19.3)	20 (16.1)	15 (18.5)	11 (23.4)	265 (18.8)	57 (16.3)	
All good	215 (10.6)	101 (12.8)	8 (16.7)	2 (8.3)	17 (14.9)	43 (34.7)	8 (9.9)	2 (4.3)	127 (9.0)	23 (6.6)	
Let us say that a pig organ transplant will work as well as a human organ transplant. If you needed an organ, how likely would you be to agree to take a pig organ instead of a human organ if you could get the pig organ much faster?											0.0005
Extremely unlikely	251 (12.4)	96 (12.1)	6 (12.5)	4 (16.7)	17 (14.9)	22 (17.7)	9 (11.1)	5 (10.6)	157 (11.2)	64 (18.3)	
Somewhat unlikely	254 (12.6)	88 (11.1)	3 (6.3)	4 (16.7)	11 (9.6)	11 (8.9)	10 (12.3)	11 (23.4)	154 (11.0)	48 (13.8)	
Not unlikely or likely	361 (17.8)	138 (17.5)	6 (12.5)	5 (20.8)	21 (18.4)	15 (12.1)	20 (24.7)	8 (17.0)	282 (20.0)	74 (21.1)	
Somewhat likely	739 (36.5)	287 (36.3)	20 (41.7)	5 (20.8)	41 (36.0)	31 (25.0)	29 (35.8)	15 (31.9)	531 (37.7)	111 (31.8)	
Extremely likely	418 (20.7)	182 (23.0)	13 (27.1)	6 (25.0)	24 (21.1)	45 (36.3)	13 (16.1)	8 (17.0)	283 (20.1)	52 (14.9)	

(Continues)

TABLE 2 | (Continued)

	Christian 2023 (40.4)	Catholic 791 (15.8)	Mormon 48 (1.0)	Orthodox 24 (0.5)	Jewish 114 (2.3)	Muslim 124 (2.5)	Buddhist 81 (1.6)	Hindu 47 (1.0)	None 1407 (28.1)	Other 349 (7.0)	*p* value
Let us say that a pig organ transplant will work as well as a human organ transplant. If you needed an organ, how likely would you be to accept a pig organ while still planning to get a human organ when it becomes available, even though you would need an extra surgery to remove the pig organ and replace it with the human organ?											<0.0001
Extremely unlikely	300 (14.8)	120 (15.2)	7 (14.6)	4 (16.7)	18 (15.8)	27 (21.8)	7 (8.6)	8 (17.0)	227 (16.1)	74 (21.2)	
Somewhat unlikely	350 (17.3)	119 (15.0)	9 (18.7)	3 (12.5)	25 (21.9)	11 (8.9)	13 (16.1)	8 (17.0)	280 (19.9)	58 (16.6)	
Not unlikely or likely	404 (20.0)	137 (17.3)	11 (22.9)	6 (25.0)	16 (14.0)	11 (8.9)	22 (27.2)	14 (29.8)	326 (23.2)	83 (23.8)	
Somewhat likely	663 (32.8)	267 (33.8)	13 (27.1)	6 (25.0)	35 (30.7)	26 (21.0)	29 (35.8)	15 (31.9)	383 (27.2)	88 (25.2)	
Extremely likely	306 (15.1)	148 (18.7)	8 (16.7)	5 (20.8)	20 (17.5)	49 (39.5)	10 (12.3)	2 (4.3)	191 (13.6)	46 (13.2)	
Currently, we do not know whether pig organs will work better or worse in humans than human organs. Knowing this, if you needed an organ and you were able to be in a research experiment where you could get a pig organ to see if it would work, how likely would you be to agree to be in this experiment?											<0.0001
Extremely unlikely	487 (24.1)	161 (20.3)	11 (22.9)	5 (20.8)	34 (29.8)	24 (19.4)	15 (18.5)	12 (25.5)	330 (23.5)	108 (30.9)	
Somewhat unlikely	361 (17.8)	149 (18.8)	10 (20.8)	2 (8.3)	17 (14.9)	12 (9.7)	18 (22.2)	4 (8.5)	282 (20.0)	52 (14.9)	
Not unlikely or likely	422 (20.9)	155 (19.6)	7 (14.6)	7 (29.2)	14 (12.3)	14 (11.3)	22 (27.2)	15 (31.9)	339 (24.1)	93 (26.7)	
Somewhat likely	541 (26.7)	213 (26.9)	15 (31.3)	7 (29.2)	36 (31.6)	34 (27.4)	17 (21.0)	12 (25.5)	349 (24.8)	73 (20.9)	
Extremely likely	212 (10.5)	113 (14.3)	5 (10.4)	3 (12.5)	13 (11.4)	40 (32.3)	9 (11.1)	4 (8.5)	107 (7.6)	23 (6.6)	

(Continues)

TABLE 2 | (Continued)

	Christian 2023 (40.4)	Catholic 791 (15.8)	Mormon 48 (1.0)	Orthodox 24 (0.5)	Jewish 114 (2.3)	Muslim 124 (2.5)	Buddhist 81 (1.6)	Hindu 47 (1.0)	None 1407 (28.1)	Other 349 (7.0)	*p* value
How much less or more willing would you be to get a pig organ if it meant that you would be watched, or monitored, for the rest of your life for the purposes of your own health/public health? Would you be:											<0.0001
Much less willing	386 (19.1)	118 (14.9)	11 (22.9)	5 (20.8)	23 (20.2)	20 (16.1)	15 (18.5)	13 (27.7)	289 (20.5)	89 (25.5)	
Somewhat less willing	325 (16.1)	119 (15.0)	7 (14.6)	4 (16.7)	16 (14.0)	8 (6.4)	20 (24.7)	8 (17.0)	245 (17.4)	48 (13.8)	
No change	677 (33.5)	239 (30.2)	20 (41.7)	6 (25.0)	36 (31.6)	25 (20.2)	20 (24.7)	13 (27.7)	501 (35.6)	119 (34.1)	
Somewhat more willing	412 (20.3)	195 (24.7)	5 (10.4)	5 (20.8)	22 (19.3)	27 (21.8)	20 (24.7)	8 (17.0)	270 (19.2)	63 (18.0)	
Much more willing	223 (11.0)	120 (15.2)	5 (10.4)	4 (16.7)	17 (14.9)	44 (35.5)	6 (7.4)	5 (10.6)	102 (7.3)	30 (8.6)	
How concerned would you be about getting an organ from a pig if there was a risk of getting a new infection from the pig organ once it was in your body, even if this risk was thought to be very low?											0.0001
Not at all concerned	91 (4.5)	38 (4.8)	2 (4.2)	0	5 (4.4)	10 (8.1)	1 (1.2)	1 (2.1)	63 (4.5)	14 (4.0)	
Slightly concerned	338 (16.7)	116 (14.7)	10 (20.8)	3 (12.5)	10 (8.8)	11 (8.9)	13 (16.1)	5 (10.6)	268 (19.0)	49 (14.0)	
Somewhat concerned	491 (24.2)	182 (23.0)	11 (22.9)	9 (37.5)	26 (22.8)	15 (12.1)	18 (22.2)	11 (23.4)	366 (26.0)	83 (23.8)	
Moderately concerned	416 (20.6)	196 (24.8)	5 (10.4)	4 (16.7)	31 (27.2)	27 (21.8)	20 (24.7)	11 (23.4)	318 (22.6)	70 (20.1)	
Extremely concerned	687 (34.0)	259 (32.7)	20 (41.7)	8 (33.3)	42 (36.8)	61 (49.1)	29 (35.8)	19 (40.4)	392 (27.9)	133 (38.1)	
What, if any, is your biggest concern about putting pig organs into humans?											<0.0001
Current lack of evidence about success rates/outcomes	591 (29.2)	231 (29.2)	12 (25.0)	10 (41.7)	29 (25.4)	42 (33.9)	21 (25.9)	11 (23.4)	421 (29.9)	93 (26.7)	
Human body not accepting the pig organ/complications of transplant	107 (5.3)	53 (6.7)	3 (6.2)	2 (8.3)	10 (8.8)	5 (4.0)	4 (4.9)	6 (12.8)	139 (9.9)	29 (8.3)	
Risk of animal-to-human infection	600 (29.7)	230 (29.1)	16 (33.3)	4 (16.7)	37 (32.5)	20 (16.1)	24 (29.6)	11 (23.4)	409 (29.1)	79 (22.6)	
It isn't "natural", human organs are used for humans	247 (12.2)	120 (15.2)	9 (18.8)	2 (8.3)	16 (14.0)	12 (9.7)	17 (21.0)	8 (17.0)	183 (13.0)	39 (11.2)	
Worries about hurting animals, animal stewardship	283 (14.0)	78 (9.9)	6 (12.5)	1 (4.2)	13 (11.4)	17 (13.7)	9 (11.1)	3 (6.4)	150 (10.7)	69 (19.8)	

(Continues)

TABLE 2 | (Continued)

	Christian 2023 (40.4)	Catholic 791 (15.8)	Mormon 48 (1.0)	Orthodox 24 (0.5)	Jewish 114 (2.3)	Muslim 124 (2.5)	Buddhist 81 (1.6)	Hindu 47 (1.0)	None 1407 (28.1)	Other 349 (7.0)	*p* value
I have no concerns about this	59 (2.9)	30 (3.8)	0	2 (8.3)	2 (1.8)	22 (17.7)	2 (2.5)	3 (6.4)	7 (0.5)	13 (3.7)	
Religious concerns/shouldn't play God	124 (6.1)	43 (5.4)	2 (4.2)	3 (12.5)	7 (6.1)	5 (4.0)	2 (2.5)	5 (10.6)	86 (6.1)	21 (6.0)	
Other (all or more than one concern above)	12 (0.6)	6 (0.7)	0	0	0	1 (0.8)	2 (2.5)	0	12 (0.8)	6 (1.7)	
How would you feel about transplanting monkey organs into humans instead of pig organs?											<0.0001
Better	262 (13.0)	126 (15.9)	6 (12.5)	5 (20.8)	22 (19.3)	62 (50.0)	17 (21.0)	10 (21.3)	147 (10.5)	39 (11.2)	
Worse	462 (22.8)	162 (20.5)	11 (22.9)	7 (29.2)	11 (9.7)	25 (20.2)	16 (19.8)	10 (21.3)	273 (19.4)	91 (26.1)	
The same	1299 (64.2)	503 (63.6)	31 (64.6)	12 (50.0)	81 (71.0)	37 (29.8)	48 (59.2)	27 (57.4)	987 (70.1)	219 (62.7)	
How would you feel about transplanting cow organs into humans instead of pig organs?											<0.0001
Better	172 (8.5)	100 (12.6)	1 (2.1)	4 (16.7)	12 (10.5)	61 (49.2)	4 (4.9)	4 (8.5)	49 (3.5)	18 (5.2)	
Worse	493 (24.4)	194 (24.5)	15 (31.2)	8 (33.3)	23 (20.2)	23 (18.5)	24 (29.6)	15 (31.9)	308 (21.9)	106 (30.4)	
The same	1358 (67.1)	497 (62.8)	32 (66.7)	12 (50.0)	79 (69.3)	40 (32.3)	53 (65.4)	28 (59.6)	1050 (74.6)	225 (64.5)	
How would you feel about transplanting dog organs into humans instead of pig organs?											
Better	144 (7.1)	74 (9.3)	1 (2.1)	4 (16.7)	15 (13.2)	52 (41.9)	6 (7.4)	6 (12.8)	45 (3.2)	16 (4.6)	
Worse	916 (45.3)	355 (44.9)	22 (45.8)	12 (50.0)	39 (34.2)	32 (25.8)	37 (45.7)	19 (40.4)	678 (48.2)	177 (50.7)	
The same	963 (47.6)	362 (45.8)	25 (52.1)	8 (33.3)	60 (52.6)	40 (32.3)	38 (46.9)	22 (46.8)	684 (48.6)	156 (44.7)	

The two biggest concerns about XTx across religious groups were the current lack of evidence about success and the risk of xenozoonosis. Over 40% of Orthodox Christian respondents cited the lack of evidence as their top concern. On average the risk of animal-to-human infection was a concern among 25% across all religious beliefs ($p < 0.0001$). Respondents were asked how they would feel about transplanting organs from monkeys, cows, or dogs into humans rather than pigs. A substantial proportion of Muslim respondents were much more receptive to transplanting organs from monkeys (50%), cows (49.2%), or dogs (41.9%), than they were to pigs—a finding not associated with other religious groups.

Muslim, Catholic, and Christian respondents were less likely to have negative feelings about killing pigs for human transplants (Table 3). Muslim and Catholic respondents reported higher rates of familiarity with XTx and lower levels of discomfort with XTx, including their own self or a loved one. The association between familiarity and comfort among these two groups was confirmed significant in the regression models. Conversely, respondents from the Church of Jesus Christ of Latter-Day Saints, as well as Orthodox Christians, were the groups most likely to be unfamiliar with xenotransplantation, although the regression analysis did not indicate a significant association. Additionally, respondents who stated "none" for religious belief were the group most likely to be unfamiliar with XTx, for which the regression analysis did show a significant association.

Those respondents who answered "none" for religious preference were most likely to have negative feelings about killing pigs for human organ transplant (OR 1.26; 95% CI: 1.08–1.46) and were also the least likely to accept a xenograft even if this meant they would have to wait longer for transplantation (OR 0.85; 95% CI: 0.73–0.99). Hindu, Buddhist, and Orthodox Christian were also more likely to have negative feelings, though the regression analysis did not show this as a significant association.

Respondents across most religious traditions showed concern about the risk for xenozoonotic infection if they should receive a XTx, although the only significant association was seen among Jewish respondents (OR 1.87; 95% CI: 1.07–3.29). The only two groups that were less likely to be concerned with xenozoonosis were Mormons and those with no religion. Groups were evenly split on whether infectious disease monitoring would make them more or less willing to receive a XTx. Both Muslim and Catholic respondents expressed willingness to participate in XTx research and to submit to life-long monitoring for xenozoonoses; the non-religious respondents were least likely to participate in XTx research (OR 1.23; 95% CI: 1.07–1.42) and to submit to life-long monitoring (OR 1.41; 95% CI: 1.21–1.64). Catholic respondents were more likely to accept a XTx even as a bridge to allotransplant (OR 0.76; 95% CI: 0.64–0.91), whereas the non-religious group was least likely (OR 1.32; 95% CI: 1.15–1.53).

In the crude regression model comparing those who cited religion as their biggest concern with XTx and those who did not cite religion as their biggest concern is seen in Table 4. The demographic characteristics of the respondents who cited religion as their biggest concern are provided in Table S1. Only Muslim identity was highly associated with this concern (OR 8.71; 95% CI: 5.31–14.30; Table 4). Those who reported no religion had an inverse association with citing religion as their biggest concern (OR 0.12; 95% CI: 0.06–0.027). No other significant associations between citing religion as the biggest concern with XTx and religious belief were seen.

4 | Discussion

Catholic respondents showed significant familiarity and comfort with XTx. While the reason for this is uncertain, one possible explanation is that the Catholic Church has an official position on XTx that was published in 2001 by the Pontifical Academy for Life, the section of the Catholic Church that issues statements on bioethics and Catholic moral theology [13]. The position statement included scientific, theological, anthropological, and ethics aspects of XTx and, overall, was favorable toward initiating clinical trials. The Catholic Church is unique amongst faith groups in having an official position, though it is unclear how familiar the Catholic laity are with this particular position statement or, even if familiar, what role this has in shaping viewpoints.

Similar to Catholic respondents, Muslim respondents also expressed familiarity and comfort with XTx. In Islam, the pig is considered *haram*—forbidden. The Qur'an states, "Prohibited to you are dead animals, blood, the flesh of swine" (5:3). While the Qu'ran has clearly established the pig to be forbidden for followers of Islam, several Muslim scholars have indicated that XTx would be acceptable in order to save life [19, 21]. While Muslim respondents expressed familiarity and comfort with XTx, they also cited religion as their biggest concern with XTx. This could point to the emphasis that Muslim respondents in our study place on commands to view the pig as *haram*, while also representing Muslim faith leaders' position that saving lives supersedes other religious expectations. Muslims had the highest rates of being in need of transplant or on the transplant waitlist as well as being a transplant recipient than any other religious belief, however they also had the lowest proportion of being a registered organ donor. Muslim individuals have held concerns on whether organ donation and transplantation is allowed within their beliefs [29]. Studies that explore the existence of these concerns among Muslims in the US are needed.

Jewish respondents were most likely to be concerned with xenozoonosis from genetically modified pig-to-human transplant. In the Levitical law, the portion of Jewish scripture that defines how persons live righteously, pigs are regarded as unclean: "And the swine, because he parteth the hoof, and is cloven-footed, but cheweth not the cud, he is unclean unto you. Of their flesh ye shall not eat, and their carcasses ye shall not touch; they are unclean unto you" (Leviticus 11:7-8, JPS Tanakh 1917). This represents the divine command to refrain from eating or handling the dead body of a pig, for they are unclean. Being unclean is to be defiled—it is a determination that closely relates to holiness [30]. Defilement would separate the unclean person from other members of the community. While Jewish law (Halakha) prioritizes preservation of life, which has been reinforced by Jewish leaders messaging around XTx,18 it is possible that concerns about pigs and cleanliness, and keeping dietary laws, extend to concerns about xenozoonoses.

TABLE 3 | Associations of religious beliefs with unfavorable attitudes to xenotransplantation.

	Unfamiliar with XTx	Uncomfortable with XTx for all	Uncomfortable with XTx for self	Uncomfortable with XTx for loved one	Negative feelings about killing pigs for humans	Unlikely to accept even if pig organ meant faster Tx	Unlikely to accept even as bridge to Tx	Unlikely to participate in XTx experiment	Less willing due to life-long monitoring	Concerned about xeno-zoonosis
Christian (non-Catholic)	1.01 (0.87–1.18)	1.12 (0.98–1.28)	1.11 (0.98–1.25)	1.12 (0.99–1.27)	**0.87 (0.76–0.99)**	1.02 (0.89–1.17)	0.88 (0.77–1.01)	0.97 (0.85–1.10)	1.00 (0.87–1.15)	0.96 (0.83–1.11)
Catholic	**0.71 (0.59–0.86)**	**0.74 (0.61–0.89)**	**0.78 (0.66–0.93)**	**0.77 (0.65–0.91)**	**0.81 (0.68–0.96)**	0.89 (0.74–1.08)	**0.76 (0.64–0.91)**	**0.80 (0.67–0.94)**	**0.62 (0.52–0.75)**	1.15 (0.94–1.41)
Mormon	2.58 (0.91–7.27)	1.08 (0.51–2.25)	1.18 (0.65–2.15)	1.11 (0.60–2.07)	0.94 (0.49–1.79)	0.63 (0.30–1.32)	1.05 (0.54–2.03)	0.91 (0.49–1.69)	1.61 (0.74–3.51)	0.79 (0.39–1.58
Orthodox	2.28 (0.52–9.96)	0.96 (0.38–2.41)	0.56 (0.23–1.34)	0.66 (0.28–1.56)	1.68 (0.58–4.87)	1.69 (0.68–4.23)	0.88 (0.34–2.28)	0.61 (0.23–1.60)	0.89 (0.35–2.25)	1.52 (0.43–5.42)
Jewish	0.89 (0.54–1.45)	0.84 (0.54–1.29)	0.72 (0.48–1.08)	0.76 (0.50–1.14)	0.96 (0.62–1.47)	1.00 (0.64–1.57)	1.08 (0.72–1.62)	0.90 (0.61–1.34)	0.89 (0.56–1.39)	**1.87 (1.07–3.29)**
Muslim	**0.14 (0.09–0.21**)	0.73 (0.49–1.09)	**0.62 (0.42–0.91)**	**0.60 (0.41–0.88)**	**0.53 (0.36–0.79)**	1.01 (0.66–1.53)	0.69 (0.46–1.03)	**0.41 (0.27–0.62)**	**0.34 (0.22–0.53)**	1.61 (0.99–2.61)
Buddhist	0.87 (0.50–1.51)	1.63 (0.98–2.73)	1.12 (0.68–1.84)	1.37 (0.83–2.28)	1.16 (0.68–1.98)	1.05 (0.61–1.82)	0.70 (0.41–1.21)	1.10 (0.66–1.86)	1.20 (0.72–2.01)	1.34 (0.73–2.43)
Hindu	1.26 (0.55–2.88)	0.97 (0.48–1.95)	1.04 (0.54–1.99)	1.08 (0.55–2.13)	1.24 (0.61–2.48)	1.62 (0.85–3.09)	1.31 (0.65–2.59)	0.87 (0.43–1.74)	1.45 (0.72–2.91)	1.91 (0.79–4.61)
None	**1.51 (1.26–1.80)**	0.97 (0.83–1.12)	1.00 (0.88–1.15)	0.97 (0.85–1.12)	**1.26 (1.08–1.46)**	**0.85 (0.73–0.99)**	**1.32 (1.15–1.53)**	**1.23 (1.07–1.42)**	**1.41 (1.21–1.64)**	0.76 (0.65–0.89)
Other	**1.49 (1.08–2.04)**	**1.41 (1.08–1.85)**	**1.44 (1.12–1.84)**	**1.48 (1.15–1.89)**	**1.62 (1.22–2.13)**	**1.66 (1.29–2.13)**	**1.39 (1.08–1.79)**	**1.49 (1.14–1.93)**	**1.34 (1.02–1.76)**	1.24 (0.93–1.67)

All above are reported as OR (95% confidence intervals) and significant associations are bolded.

TABLE 4 | Crude association with religious belief and citing religion as their top concern with xenotransplantation (XTx).

	Citing religion as the biggest concern with XTx OR (95% CI)
Christian (non-Catholic)	1.08 (0.76–1.51)
Catholic	1.47 (0.97–2.22)
Mormon[a]	—
Orthodox	3.19 (0.74–13.71)
Jewish	0.61 (0.15–2.51)
Muslim	**8.71 (5.31–14.30)**
Buddhist	0.87 (0.21–3.61)
Hindu	2.40 (0.73–7.82)
None	**0.12 (0.06–0.27)**
Other	1.38 (0.77–2.46)

[a]Model fit not appropriate due to small numbers unable to compute.

Respondents were asked about issues of animal welfare and, specifically, how they felt about "raising and killing pigs in order to take their organs and put them into humans." The Muslim, Catholic, and Christian respondents were less likely to have negative feelings about killing pigs for human organs. There is no prohibition in Catholic or Protestant Christianity about killing specific animals for food or other uses. However, in Islam, as aforementioned, pigs are *haram*. One possible explanation to account for why followers of Islam are less likely to have negative feelings about killing pigs for human organs is that there is a lack of emotional attachment to pigs, and some may even see the killing of pigs as a positive. Nevertheless, the Muslim group was the only religious group that felt better about transplanting organs from monkeys, cows, or dogs into humans rather than pigs. Hence, there may be some association with the pig being *haram* and individuals not wanting a pig organ inside their body. While followers of Judaism have similar doctrinal prohibitions regarding the consumption of pork, this reasoning did not extend to those who identify as Jewish in the survey.

There were a minority of respondents from each religious tradition who stated that their greatest concern with XTx was religious concerns, including that humankind should not play God. This objection to XTx has been repeated in lay level publications [31] and has also been previously reported in empirical studies, including in a recent focus group study with religious leaders in which one participant defined "playing God" as "over stepping what the Creator has provided" [23].

Very little is known empirically about the viewpoints of smaller religious groups, such as the Church of Jesus Christ of Latter-Day Saints, as well as myriad Protestant denominations, toward XTx. Furthermore, little is known about how religious and philosophical systems that do not have large followings in Western countries view XTx, such as Bahá'í, Buddhism, Confucianism, Jainism, Shinto, Sikhism, and Taoism. Not only are empirical data on viewpoints lacking for many of these faith groups, but little or no normative or descriptive ethics work has been done. More studies are needed to understand these perspectives.

This study has certain limitations. While the demographics of the survey respondents generally reflect those of the US population, respondents were recruited and paid by a private survey firm. This method of data collection could influence the generalizability of our findings and may introduce a selection bias. The majority of Mormon respondents were women with no significant associations with negative attitudes toward XTx found in our study. Gender differences in XTx acceptance have been previously noted, and women have expressed higher disapproval than men toward XTx [32]. In contrast, Muslim respondents in our study were predominantly male and expressed being more comfortable with certain aspects of XTx than other religious groups. It is important to consider gender bias as a factor that could have influenced the results among these two religious groups. Furthermore, almost one quarter of Muslim respondents were in need of an organ or on the transplant waitlist, potentially overrepresenting their positive attitudes towards XTx due to their clinical state at the time of the survey. Although our results provide insights into public attitudes toward XTx, the survey's Likert scale design did not give us the opportunity to explore the reasons behind specific responses in any qualitative manner. We also remain cognizant that attitudes are fluid, changing with scientific progress, cultural dynamics, and other social phenomena, which means they can vary based on when a survey is conducted. Even though we measured self-reported familiarity with XTx, we did not assess the respondents' actual knowledge of XTx, so the correlation between their knowledge and acceptance of XTx remains unclear. Association seen in this study may have been due to confounders with religion and not driven by religious beliefs themselves. Furthermore, across all religions, there may be disparity between official positions of religious leaders and the beliefs of groups and individuals that belong to the faiths of these leaders, and between different groups within each religion. The correlations identified as significant in this paper might diverge from the positions published from faith group leaders, and might diverge from the beliefs of specific groups within each faith group.

5 | Conclusion

This is the largest survey study conducted to date in the US that has associated religious identity with viewpoints on XTx. As XTx progresses from pre-clinical studies to clinical trials and potentially to clinical therapy, hesitations exist. Very little is still known about certain minority religious traditions in the US. Specific studies should be designed that are intended to understand these viewpoints.

Author Contributions

D.J.H. drafted the initial manuscript. L.A.P. performed the analysis and contributed to specific portions of the manuscript. L.L.K. led the survey design and data collection. A.Z., B.P., and L.L.K. contributed to specific portions of the manuscript. All authors critically reviewed and revised the manuscript.

Acknowledgments

The authors would like to thank the members of the NYU Xenotransplant Ethics Public Perceptions working group—Asma Alzaidy, Bernadette Tobin, Bonnie Venter, Bruce Gelb, David Shabtai, Nancy Dubler (in memoriam), Peter Reese, Samantha Klitenic and Sylvia Rosas—for their valuable input on the survey design and dissemination strategy.

Disclosure

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

References

1. J. E. Locke, V. Kumar, D. Anderson, and P. M. Porrett, "Normal Graft Function After Pig-to-Human Kidney Xenotransplant," *JAMA Surgery* 158, no. 10 (2023): 1106–1108, https://doi.org/10.1001/jamasurg.2023.2774.

2. P. M. Porrett, B. J. Orandi, V. Kumar, et al., "First Clinical-Grade Porcine Kidney Xenotransplant Using a Human Decedent Model," *American Journal of Transplantation* 22, no. 4 (2022): 1037–1053, https://doi.org/10.1111/ajt.16930.

3. R. A. Montgomery, J. M. Stern, B. E. Lonze, et al., "Results of Two Cases of Pig-to-Human Kidney Xenotransplantation," *New England Journal of Medicine* 386, no. 20 (2022): 1889–1898, https://doi.org/10.1056/NEJMoa2120238.

4. N. Moazami, J. M. Stern, K. Khalil, et al., "Pig-to-Human Heart Xenotransplantation in Two Recently Deceased Human Recipients," *Nature Medicine* 29, no. 8 (2023): 1989–1997, https://doi.org/10.1038/s41591-023-02471-9.

5. M. M. Mohiuddin, A. K. Singh, L. Scobie, et al., "Graft Dysfunction in Compassionate Use of Genetically Engineered Pig-to-Human Cardiac Xenotransplantation: A Case Report," *Lancet* 402, no. 10399 (2023): 397–410, https://doi.org/10.1016/S0140-6736(23)00775-4.

6. H. G. Koenig, *Spirituality in Patient Care*, 3rd ed. (Templeton Press, 2013).

7. F. Rego, F. Gonçalves, S. Moutinho, L. Castro, and R. Nunes, "The Influence of Spirituality on Decision-Making in Palliative Care Outpatients: A Cross-Sectional Study," *BMC Palliative Care* 19, no. 1 (2020): 22, https://doi.org/10.1186/s12904-020-0525-3.

8. G. A. Silvestri, S. Knittig, J. S. Zoller, and P. J. Nietert, "Importance of Faith on Medical Decisions Regarding Cancer Care," *Journal of Clinical Oncology* 21, no. 7 (2003): 1379–1382, https://doi.org/10.1200/JCO.2003.08.036.

9. H. G. Koenig, "Religious Attitudes and Practices of Hospitalized Medically Ill Older Adults," *International Journal of Geriatric Psychiatry* 13, no. 4 (1998): 213–224, https://doi.org/10.1002/(sici)1099-1166(199804)13:4⟨213::aid-gps755⟩3.0.co;2-5.

10. H. G. Koenig, D. E. King, and V. B. Carson, "Appendix," *Handbook of Religion and Health*, 2nd ed. (Oxford University Press, 2012): 610–643.

11. C. Mitchell, A. Lipps, L. Padilla, Z. Werkheiser, D. K. C. Cooper, and W. Paris, "Meta-Analysis of Public Perception Toward Xenotransplantation," *Xenotransplantation* 27, no. 4 (2020): e12583, https://doi.org/10.1111/xen.12583.

12. I. DeLaura, I. J. Anwar, J. Ladowski, A. Patino, S. Cantrell, and S. Sanoff, "Attitudes of Patients With Renal Disease on Xenotransplantation: A Systematic Review," *Xenotransplantation* 30, no. 2 (2023): e12794, https://doi.org/10.1111/xen.12794.

13. Pontifical Academy for Life. Prospects for Xenotransplantation: Scientific and Ethical Considerations, Vatican, accessed September 27, 2024, http://www.vatican.va/roman_curia/pontifical_academies/acdlife/documents/rc_pa_acdlife_doc_20010926_xenotrapianti_en.html.

14. W. Paris, R. J. H. Seidler, K. FitzGerald, A. I. Padela, E. Cozzi, and D. K. C. Cooper, "Jewish, Christian and Muslim Theological Perspectives About Xenotransplantation," *Xenotransplantation* 25, no. 3 (2018): e12400, https://doi.org/10.1111/xen.12400.

15. J. Sautermeister, R. Mathieu, and V. Bogner, "Xenotransplantation-Theological-Ethical Considerations in an Interdisciplinary Symposium," *Xenotransplantation* 22, no. 3 (2015): 174–182, https://doi.org/10.1111/xen.12163.

16. D. J. Hurst, D. Rodger, V. K. Pizutelli, and V. Danser. "Religious Viewpoints: Protestant and Catholic," in *Xenotransplantation: Ethical, Regulatory, and Social Aspects*, ed. D. J. Hurst, L. Padilla, and W. D. Paris (Springer International Publishing, 2023), 151–162.

17. I. Bedzow, "Religious Viewpoints: Judaism," in *Xenotransplantation: Ethical, Regulatory, and Social Aspects*, ed. D. J. Hurst, L. Padilla, and W. D. Paris (Springer International Publishing, 2023), 187–197.

18. J. D. Loike and R. M. Krupka, "The Jewish Perspectives on Xenotransplantation," *Rambam Maimonides Medical Journal* 14, no. 4 (2023): e0024, https://doi.org/10.5041/RMMJ.10511.

19. M. Ali, U. Maravia, and A. I. Padela, "Religious Viewpoints: Sunni Islam," in *Xenotransplantation: Ethical, Regulatory, and Social Aspects*, ed. D. J. Hurst, L. Padilla, and W. D. Paris (Springer International Publishing, 2023), 163–177.

20. M. F. Mohd Zailani, M. N. Hamdan, and A. N. Mohd Yusof, "Human-Pig Chimeric Organ in Organ Transplantation From Islamic Bioethics Perspectives," *Asian Bioethics Review* 15, no. 2 (2023): 181–188, https://doi.org/10.1007/s41649-022-00233-2.

21. K. Aramesh, "Religious Viewpoints: Shia Islam," in *Xenotransplantation: Ethical, Regulatory, and Social Aspects*, ed. D. J. Hurst, L. Padilla, and W. D. Paris (Springer International Publishing, 2023): 179–186.

22. J. Gielen, "Religious Viewpoints: Hinduism," in *Xenotransplantation: Ethical, Regulatory, and Social Aspects*, ed. D. J. Hurst, L. Padilla, and W. D. Paris (Springer International Publishing, 2023): 199–208.

23. D. J. Hurst, L. A. Padilla, D. K. Cooper, W. Walters, and W. Paris, "The Attitudes of Religious Group Leaders Towards Xenotransplantation: A Focus Group Study," *Xenotransplantation* 29, no. 5 (2022): e12777, https://doi.org/10.1111/xen.12777.

24. D. J. Hurst, L. A. Padilla, D. K. C. Cooper, and W. Paris, "Factors Influencing Attitudes Toward Xenotransplantation Clinical Trials: A Report of Focus Group Studies," *Xenotransplantation* 28, no. 4 (2021): e12684, https://doi.org/10.1111/xen.12684.

25. D. J. Hurst and D. K. C. Cooper, "The Importance of Public Engagement in Clinical Xenotransplantation," *Health Care Science* 3, no. 2 (2024): 124–130, https://doi.org/10.1002/hcs2.91.

26. L. A. Padilla, D. J. Hurst, A. Zink, B. Parent, and L. L. Kimberly, "Public Attitudes to Xenotransplantation: A National Survey in the United States," *American Journal of Transplantation* 24, no. 11 (2024): 2066–2079, https://doi.org/10.1016/j.ajt.2024.07.018.

27. L. A. Padilla, D. Hurst, R. Lopez, V. Kumar, D. K. C. Cooper, and W. Paris, "Attitudes to Clinical Pig Kidney Xenotransplantation Among Medical Providers and Patients," *Kidney360* 1, no. 7 (2020): 657–662, doi:10.34067/kid.0002082020.

28. Pew Research Center. "Religious Landscape Study," accessed July 16, 2024, https://www.pewresearch.org/religious-landscape-study/database/.

29. NHS, "New Fatwa to Clarify Islamic Position on Organ Donation," updated June 19, 2019, https://www.organdonation.nhs.uk/get-involved/news/new-fatwa-published-to-clarify-islamic-position-on-organ-donation/.

30. J. Neusner, "The Idea of Purity in Ancient Judaism," *Journal of the American Academy of Religion* 43, no. 1 (1975): 15–26.

31. J. Barber, "Debating Xenotransplantation: Xenotransplantation Is Unethical," *Liberty Champion* 2024, https://www.liberty.edu/champion/2024/02/debating-xenotransplantation-xenotransplantation-is-unethical/.

32. G. Andrade, E. AboHamza, Y. Elsantil, A. Ayoub, and D. Bedewy, "Moral Approval of Xenotransplantation in Egypt: Associations With Religion, Attitudes Towards Animals and Demographic Factors," *BMC Medical Ethics [Electronic Resource]* 25, no. 1 (2024): 19, https://doi.org/10.1186/s12910-024-01013-3.

Supporting Information

Additional supporting information can be found online in the Supporting Information section.