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Rodent surgeries: who is performing them and how?

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Abstract

Surgery is an integral part of many experimental studies. Good surgical practice is a prerequisite for surgical success, optimal animal welfare, and it not only improves post-operative recovery but also the overall outcome and validity of a study. Rodents, especially mice, are the most commonly used laboratory animals and the legal requirements to perform experimental surgery are identical for all species. However, minimum surgical training requirements vary significantly across countries, ranging from basic introductory courses in animal experimentation to supervised, advanced courses led by expert surgeons; this complicates efforts toward standardization. This study provides insight into surgical education and experience, available infrastructure, workplace satisfaction, and the application of good surgical practice in laboratory rodent surgery. Two online surveys with a total of 72 questions were distributed across Europe and 782 complete responses were received and subsequently analyzed. The results showed that most researchers performing rodent surgery have no medical background. Furthermore, good surgical practice (i.e., sterile gowning and gloving, decontaminating and draping the patient, using sterile equipment) seems to be poorly implemented in rodent surgery. In addition, half of all rodent surgeons have no assistance available and most respondents expressed a desire for continued education and courses to deepen and refine their surgical skills. Consequently, training for rodent surgery should be tailored to the surgeon's preexisting knowledge, and additional surgical training should be made mandatory before performing surgery on laboratory rodents. This could improve both the animals' and the surgeons' welfare.

Keywords

3Rs, refinement, teaching and training, welfare, surgery

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Introduction

Rodents are the predominant species used in animal experiments, with a substantial number of them undergoing surgical interventions.[1–3] Animal welfare during and after surgery largely depends on the quality and professional competence of the personnel performing and supervising the procedures.[4]

A dedicated and practical training in surgery should provide the necessary knowledge and skills to prepare the surgeon to operate safely and successfully on the patient. This training should include the basic principles of good surgical practice, such as surgical hand disinfection, sterile gowning and gloving, decontaminating and draping the patient as well as the use of sterile equipment and adherence to aseptic techniques.[5–10] Such training is usually an essential part of medical and veterinary curricula but is rarely included in other academic programs.

EU Directive 2010/63 requires adequate surgical infrastructure and training for surgeons but delegates the responsibility of describing minimal standards to member states.[4] Additional literature provided by the

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European Commission offers further recommendations in the form of task-specific surgical training modules.[11] However, while some European countries require dedicated surgical training,[12,13] a basic introductory course in animal experimentation (Federation of European Laboratory Animal Science Associations (FELASA) Function A) may provide sufficient eligibility to start performing surgery on laboratory animals in others.[14]

Bad surgical practice can lead to surgical site infections (SSIs), increasing post-operative morbidity and mortality.[15] SSIs often develop subclinically in rodents, which show few typical signs of sepsis or infection.[16,17] Therefore, in addition to having a good familiarity with the surgical model itself, a profound knowledge of good surgical practice not only helps to improve animal well-being after surgery but also enhances the quality of the obtained data.

The legal requirements to perform experimental surgery are identical for rodents and large animals, and good surgical practice should be used regardless of the patient's size. In addition, specific considerations must be taken into account for laboratory rodents, which are different from other species, for example, the need for a specific (micro)surgical setup and dedicated instruments, the large number of identical surgeries to be performed ("batch surgery"), or the use of genetically modified or immunocompromised rodents. Unfortunately, official guidelines specifically on rodent surgery are inconsistent and scarce in Europe at the time of writing this manuscript.

As self-evident as good surgical practice principles might appear for experienced surgeons, they may be difficult to implement for untrained personnel. Moreover, acquiring the necessary knowledge and skills takes time and effort, and regular retraining is essential. Consequently, it remains unclear whether the current training programs adequately equip individuals with the necessary competencies to perform rodent surgery.

This study aimed to gain insight into the surgical experience, available infrastructure, workplace satisfaction, and application of good surgical practice of persons performing laboratory rodent surgery, via online surveys distributed across Europe. The resulting data should help to develop tailored guidelines, recommendations, and training courses to improve the current situation.

Materials and methods

Study design and survey structure

This cross-sectional study was divided into two online surveys (LimeSurvey GmbH, Hamburg, Germany. URL www.limesurvey.org, Version 3.27.24). The first survey featured 26 questions, of which 17 were mandatory, 3 were voluntary, and 6 were conditional. These questions were organized into four sections: "Basic information about you" and "Workplace and professional knowledge" assessed demographic data and the general workplace environment. "Details about surgery" gathered information on performed surgeries, while "Given conditions" provided the chance to collect opinions and subjective views on the workplace, equipment, and job perspective. As survey instruments, the following types of questions were utilized: numerical input: 1, single choice: 6, free text field: 5, multiple choice: 8, array by column: 2, array dual scale: 1, array: 2, and ranking: 1, with an additional two free text fields for email addresses to participate in the lottery and/or consent to being informed about the results of the study via email. The second survey focused on detailed information about the surgical procedures performed by the survey respondents, the surgical infrastructure, preoperative preparation, anesthesia and analgesia, the post-operative care provided, and finally, whether terminal and/or survival procedures were performed. The 46 question total (24 mandatory, 2 voluntary, and 20 conditional) was divided into single choice: 4, free text field: 15, multiple choice: 12, array dual scale: 2, array: 10, and multiple choice with comments: 3, and again, had an additional two free text fields for email addresses to participate in the lottery and/or consent to being informed about the results of the study via email. The entire questionnaire and more data can be accessed in the supplementary material section.

Email invitations for each survey were sent out Europewide. With *in vivo* researchers and rodent surgeons as the primary target audience, various organizations, societies, and entities in the field of laboratory animal research were asked to send out online survey invitations to their members (e.g., FELASA, European Society of Laboratory Animal Veterinarians, European College of Laboratory Animal Medicine, Norway's National Consensus Platform for the advancement of "the 3 Rs," National Centre for the Replacement, Refinement and Reduction of Animals in Research, Understanding Animal Research). PDF versions of the invitations, with the online survey accessible via hyperlink or QR code, were additionally sent as attachments in the emails. Social media posts on LinkedIn (www.linkedin.com) and Twitter (www.twitter.com) further spread the survey invitations. All invitations and questionnaires were provided in English, French, and German.

Pretests of the survey were conducted by the first author to ensure functionality and comprehensibility, especially in relation to the dichotomous question paths. After the survey was opened, any additional test runs were marked as such and individuals performing the test runs of the survey were not considered for participation afterwards.

Participation in the surveys was anonymous and open from March 10 to November 27, 2020, with staggered distribution of the questionnaires as follows: the first survey opening on March 10, 2020, and the follow-up survey starting from September 21, 2020. On release of the follow-up survey, respondents had the option to complete either only the follow-up survey or both surveys in one session. By requiring each respondent to create a personalized token before starting the questionnaires, both surveys could be merged while maintaining respondent anonymity. For the respondents completing the survey twice, the second survey entry was discarded. Furthermore, only fully completed questionnaires were accepted for data analysis.

Statistical analysis

Raw data were exported from the online survey tool (LimeSurvey GmbH, Hamburg, Germany. URL http://www.limesurvey.org, Version 3.27.24) as .csv files (Microsoft Excel, Version 2202, Build 14931.20660) and descriptive statistics were performed on all variables using R version 4.0.5 (2021-03-31).[18] Proportions and 95% confidence intervals (CIs) were calculated using the commands BinomCI (method = Jeffreys) and MultinomCI, with a maximum of three digits after the decimal separator for the results (package: DescTools).[19] In the text, CIs are displayed in square brackets, starting with the lower limit followed by the upper limit (e.g., [44.4; 66.6]). For the creation of word clouds, all responses were treated as text corpora and transformed into data frames containing the words and their respective frequency. Stop words, punctuation, articles, and commonly occurring but non-topic-specific words were removed (packages: wordcloud and wordcloud2).[20,21] The conditional inference tree was created incorporating the variables Age, Highest educational degree, Educational background, Professional experience in years, Surgical experience outside of research, Acquisition of surgical skills, and Availability of surgical help (package: party).[22] Here, the default alpha level of 0.05 was considered and the p-values were adjusted for multiplicity (Bonferroni method).

Results

A total of 879 responses were collected for the first survey with 380 (43.2%) partial responses and 499 (56.8%) full responses. A total of 656 responses were collected for the follow-up survey, with 373 (56.9%) partial and 283 (43.1%) full responses. In total, 782 responses were analyzed.

Surgeons

Demographics. The respondents were between 20 and 74 years of age, with a mean of 40.8 years. The 35–49 age group represented the largest proportion (42.9%), followed by 18–34-year-olds (33.6%), 50–65-year-olds (22.3%), and those over 65 years of age (1.1%). Some 58.1% were female and 40.1% male, while 1.8% did not specify. The four most frequently stated nationalities were German (20.5%), French (18.2%), Swiss (16.1%), and British (7.6%). The remaining 37.6% were of different nationalities (Table 1 suppl.).

Educational background. A doctor's or PhD degree was held by 42.4% of the respondents, 34.8% held a diploma, bachelor's, or master's degree, 11.9% held a habilitation/professorship, and 10.9% held an apprenticeship or similar qualification (Table 1). Over half of the respondents had studied in the field of life sciences (52.9%), almost a quarter had studied veterinary medicine (24.8%), followed by technicians and animal caretakers (11.1%), graduates in human medicine (9.3%), and other sciences (Table 1). Graduates of veterinary (DVMs) and medical studies (MDs) are classified in the following as medical background, respondents with a degree in life sciences or other sciences—technicians and animal caretakers are not.

Workplace. Most of the respondents worked in academia (71.5%), a quarter in industry or an independent research institution (26.3%), and only a few worked in a federal institute or other entity (Table 1). About half of the respondents worked in Switzerland (47.7%) and half outside of Switzerland (52.3%) with Germany, the UK, and France being the most frequently named countries (Table 1). A full list of the countries and workplaces can be found in the supplementary material (Table 2 suppl.).

Professional experience. Half of all respondents (50.5%) had been performing surgery on laboratory animals for over 10 years, followed by those with 3–10 years of surgical experience (29.0%) and 1–3 years (20.5%) (Table 2). Almost all respondents (96.5%) without a medical background had no surgical experience with other species, while more than half (51.2%) the respondents with a medical background did. Moreover, there was a significant difference in surgical experience outside of animal research between respondents with a medical background, 18.7% [12.0; 26.1], and those without, 0.7% [0.0; 2.3] (Table 2).

Acquisition of surgical skills. A total of 21.3% of the respondents had received training exclusively from colleagues, 3.7% through the academic curriculum during

Table 1. Demographics, professional experience, and workplace. Sample sizes differ because questions have been optional to answer.

Demographic data	All, *n* (%)	Medical background* Yes, *n* (%)	Medical background* No, *n* (%)
Age in years			
18–34	206 (33.6)	48 (23.0)	158 (39.1)
35–49	263 (42.9)	93 (44.5)	170 (42.1)
50–65	137 (22.3)	65 (31.1)	72 (17.8)
>65	7 (1.1)	3 (1.4)	4 (1.0)
	$n=613$	$n=209$	$n=404$
Gender			
Female	357 (58.1)	116 (55.5)	241 (59.5)
Male	246 (40.1)	87 (41.6)	159 (39.3)
Other[a]	11 (1.8)	6 (2.9)	5 (1.2)
	$n=614$	$n=209$	$n=405$
Nationality			
German	116 (20.5)	51 (25.9)	65 (17.6)
French	103 (18.2)	14 (7.1)	89 (24.1)
Swiss	91 (16.1)	27 (13.7)	64 (17.3)
British	43 (7.6)	12 (6.1)	31 (8.4)
Other	213 (37.6)	93 (47.2)	120 (32.5)
	$n=566$	$n=197$	$n=369$
Highest educational degree			
Bachelor's/master's/diploma	214 (34.8)	49 (23.4)	165 (40.6)
Doctor/PhD	261 (42.4)	116 (55.5)	145 (35.7)
Habilitation/professor	73 (11.9)	31 (14.8)	42 (10.3)
Apprenticeship/other	67 (10.9)	13 (6.2)	54 (13.3)
	$n=615$	$n=209$	$n=406$
Educational background			
Veterinary medicine	152 (24.8)	152 (72.7)	
Human medicine	57 (9.3)	57 (27.3)	
Life sciences	324 (52.9)		324 (80.2)
Other sciences	12 (2.0)		12 (3.0)
Technician/animal caretaker	68 (11.1)		68 (16.8)
	$n=613$	$n=209$	$n=404$
Type of workplace			
Academia	440 (71.5)	145 (69.4)	295 (72.7)
Industry/independent research organization	162 (26.3)	56 (26.8)	106 (26.1)
Federal institution	8 (1.3)	6 (2.9)	2 (0.5)
Other	5 (0.8)	2 (1.0)	3 (0.7)
	$n=615$	$n=209$	$n=406$
Country of workplace			
Switzerland	292 (47.7)	73 (35.1)	219 (54.2)
Germany	81 (13.2)	36 (17.3)	45 (11.1)
United Kingdom	66 (10.8)	24 (11.5)	42 (10.4)
France	44 (7.2)	9 (4.3)	35 (8.7)
Other	129 (21.1)	66 (31.7)	63 (15.6)
	$n=612$	$n=208$	$n=404$

*DVMs and MDs are classified here as having a medical background, respondents with a degree in life sciences or other sciences—technicians and animal caretakers are not.
[a]Includes the options "Prefer not to answer" and "Other" with a free text field to specify.

college education, and 5.4% stated other means of acquiring surgical skills (self-taught, dedicated surgical course, or visiting an external site). Most respondents (69.5%) acquired their surgical skills through a combination of the aforementioned categories. The categories most frequently reported in these combinations were colleagues (62.2%), academic curriculum (45.0%), dedicated training course (31.6%), visiting

Table 2. Surgical experience, skills acquisition and support.

Experience and training	All, *n* (%)	Medical background* Yes, *n* (%)	Medical background* No, *n* (%)
Professional experience in years			
<1–3	126 (20.5)	39 (18.7)	87 (21.5)
3–10	178 (29.0)	52 (24.9)	126 (31.1)
>10	310 (50.5)	118 (56.5)	192 (47.4)
	n = 614	*n* = 209	*n* = 405
Surgical experience outside of animal research[a]			
Animals	120 (17.9)	107 (51.2)	13 (2.8)
Humans	42 (6.3)	39 (18.7)	3 (0.7)
None	508 (75.8)	63 (30.1)	445 (96.5)
	n = 670	*n* = 209	*n* = 461
Surgical skills acquisition[b]			
Colleague	131 (21.3)	16 (7.7)	115 (28.4)
Academic curriculum	23 (3.7)	19 (9.1)	4 (1.0)
Mixture of the listed categories	427 (69.5)	164 (78.5)	263 (64.9)
Other	33 (5.4)	10 (4.8)	23 (5.7)
	n = 614	*n* = 209	*n* = 405
Availability of help in surgical matters			
Yes	500 (81.4)	172 (82.3)	328 (81.0)
No	114 (18.6)	37 (17.7)	77 (19.0)
	n = 614	*n* = 209	*n* = 405
Helping person's role			
Colleague	398 (76.2)	135 (75.0)	263 (76.9)
	n = 522	*n* = 180	*n* = 342
Veterinarian	247 (48.9)	75 (43.4)	172 (51.8)
	n = 505	*n* = 173	*n* = 332
Animal welfare officer	172 (34.4)	48 (27.9)	124 (37.8)
	n = 500	*n* = 172	*n* = 328
Technician	110 (22.0)	38 (22.1)	72 (22.0)
	n = 500	*n* = 172	*n* = 328

*DVMs and MDs are classified here as having a medical background, respondents with a degree in life sciences or other sciences—technicians and animal caretakers are not.
[a]Animals accounts for the choice of any option or combination of small animals, farm animals, horses, birds/exotics.
[b]Other includes visits to external sites and autodidacts.

an external site (28.0%), and self-taught (24.8%) (Table 2). Publications and/or books were used exclusively by 20.5% of respondents to obtain surgery-related information, 5.2% used Google and/or YouTube and/or other online training tools exclusively, whereas the majority (74.3%) resorted to a mixture of categories. Significant differences were detected in (a) surgical skills acquired from colleagues: 7.7% [2.9; 13.2] to 28.4% [23.7; 33.1]; and (b) the mixture of all listed categories: 78.5% [73.7; 84.0] to 64.9% [60.2; 69.6], when comparing respondents with and without a medical background (Table 2). Most respondents had personal support for surgery-related questions, primarily from colleagues, followed by veterinarians, animal welfare officers (as described in EU Directive 2010/63, Art. 26 and 27), or technicians (Table 2).

Surgeries

Animal species and types of surgery. Mice were reported to be the predominantly used species, followed by (in descending order) other rodents, farm animals, rabbits, non-human primates, dogs/cats, and aquatics (Table 3). About half of the respondents performed survival surgeries, followed by a combination of survival and non-survival surgeries in around 40%, while the remaining 10% performed only non-survival surgeries. About two-thirds of the respondents performed surgeries lasting 1 h or less, while one-third performed surgeries lasting more than 1 h (Table 3).

The surgical sites most frequently operated on were abdomen (58.8%), skin (32.0%), thorax (25.4%), and extremities (22.8%). Here, respondents with a medical background (39.7% [29.1; 51.2]) performed surgeries

Table 3. Surgical procedures and surgical infrastructure.

		Medical background*	
Details about surgery	All	Yes	No
Species worked with most[a]			
Mice	1.89	3.91	1.52
Other rodents	2.50	3.49	2.06
Farm animals	3.74	4.26	2.82
Rabbits	4.31	4.69	3.37
Non-human primates	4.89	5.77	3.77
Dogs, cats	5.18	5.89	4.00
Aquatics	6.40	8.57	4.39
	$n=552$	$n=130$	$n=422$
Terminal/survival surgeries, n (%)			
Only survival	138 (50.7)	28 (38.4)	110 (55.3)
Only terminal	30 (11.0)	11 (15.1)	19 (9.5)
Both	104 (38.2)	34 (46.6)	70 (35.2)
	$n=272$	$n=73$	$n=199$
Surgical site, n (%)			
Abdomen	160 (58.8)	51 (69.9)	109 (54.8)
Thorax	69 (25.4)	18 (24.7)	51 (25.6)
Extremities	62 (22.8)	29 (39.7)	33 (16.6)
Skin	87 (32.0)	29 (39.7)	58 (29.1)
	$n=272$	$n=73$	$n=199$
Surgical duration, n (%)			
1 h or less	169 (63.8)	45 (65.2)	124 (63.3)
More than 1 h	96 (36.2)	24 (34.8)	72 (36.7)
	$n=265$	$n=69$	$n=196$
Dedicated space available for . . ., n (%)			
Surgery	244 (93.8)	66 (94.3)	178 (93.7)
	$n=260$	$n=70$	$n=190$
Surgical preparation	171 (62.9)	45 (61.6)	126 (63.3)
	$n=272$	$n=73$	$n=199$
Surgical instruments	180 (66.2)	52 (71.2)	128 (64.3)
	$n=272$	$n=73$	$n=199$
Magnification devices for surgery, n (%)			
Yes	232 (85.3)	62 (84.9)	170 (85.4)
No	40 (14.7)	11 (15.1)	29 (14.6)
	$n=272$	$n=73$	$n=199$
Assistance in surgery by species			
Farm animals, %	97.1	97.4	96.2
	($n=104$)	($n=78$)	($n=26$)
Dogs, cats, %	96.0	94.6	100.0
	($n=50$)	($n=37$)	($n=13$)
Non-human primates, %	90.9	93.5	84.6
	(n = 44)	(n = 31)	(n = 13)
Rabbits, %	82.8	82.1	85.7
	($n=99$)	($n=78$)	($n=21$)
Other rodents, %	53.0	59.7	48.1
	($n=368$)	($n=154$)	($n=214$)
Mice, %	41.6	49.2	37.9
	($n=558$)	($n=183$)	($n=375$)
Aquatics, %	35.0	27.3	44.4
	($n=20$)	($n=11$)	($n=9$)
All species combined (average percentage)	57.0	68.0	47.0

(continued)

Table 3. Continued.

Details about surgery	All	Medical background*	
		Yes	No
Why no assistance? *n* (%)			
Not necessary	157 (56.7)	44 (56.4)	113 (56.8)
Lack of personnel/funding	85 (30.7)	23 (29.5)	62 (31.2)
Other	35 (12.6)	11 (14.1)	24 (12.1)
	n = 277	*n* = 78	*n* = 199

*DVMs and MDs are classified here as having a medical background, respondents with a degree in life sciences or other sciences—technicians and animal caretakers are not.
[a]A lower score = species worked with more often.

on extremities significantly more often than respondents without a medical background (16.6% [11.9; 22.2]) (Table 3).

Surgical infrastructure. Most respondents had a dedicated surgical workplace for carrying out surgeries, one-third had a dedicated space for the surgical preparation of the animals, and another third had a dedicated space reserved for surgical instruments. Furthermore, the majority reported using magnification (e.g., surgical microscope, magnifying glasses) during surgery (Table 3).

Overall, surgical assistance was available in more than 50% of cases across all species, but more so during surgeries on large animal species (i.e., farm animals, dogs and cats, non-human primates, and rabbits) than for rodents or aquatics (Table 3). The most common reason reported for the lack of assistance was that assistance during surgeries on rodents or aquatic animals was unnecessary. The second most common reason was the lack of personnel or funding, followed by reasons such as spatial limitations, and a preference for working alone (Table 3).

Instruments. Most respondents (90.1%) reported using sterilized instruments for laboratory rodent surgery. Regarding the means of sterilization, an autoclave was most commonly used (79.4%), followed by dry heat (25.4%), while gas (7.7%) and gamma radiation (2.2%) were used less frequently (Table 4). Instruments were stored in dedicated instrument cases or pouches by most respondents, followed by any other form of closed or open storage (Table 4). Between batch surgeries (i.e., the same or similar surgical procedure performed on multiple animals in succession over a day), only a little over a third (36.0%) of the survey respondents sterilized the instruments when changing from one animal to the next (Table 4).

Personal protective equipment. About two-thirds of respondents used sterile surgical gloves (60.3%), whereas a slightly higher percentage (68.4%) stated using sterile personal protective equipment (PPE; sterile surgical gloves and/or sterile gown). Interestingly, although two-thirds of all survey respondents stated implementing a sterile gloving and/or gowning routine, only 82.9% of sterile glove users and 53.0% of sterile gown users implemented sterile routines for the respective PPE (Table 4).

Animal preparation. Fur was mainly removed using electric clippers (79.4%), with depilation cream employed by about a quarter of respondents, and wet shave or other means (plucking by hand, scissors, or none) in combination by a quarter (Table 4). Most respondents used dedicated skin disinfectants for surgical site preparation (78.3%), whereas less than half used alcohol (44.5%), and only a small percentage used soap (14.7%). Here, the subgroups differed significantly in that a third of the respondents with a medical background (32.7%) used soap to prepare the animal's surgical site, compared to only 12.4% of respondents without a medical background. Surgical draping for the animal was stated to be used by slightly more than half the respondents (56.6%), a sterile instrument resting area by half (50.4%), and perisurgical administration of antibiotics by a minority (18.4%) (Table 4).

Respondents' quality ratings

Workplace conditions. The different workplace conditions for experimental surgery (i.e., surgical expertise, overall hygiene, post-op care, and more) were generally rated favorably by respondents when comparing rodents to other mammals (Figure 1 suppl.). The lowest ratings were recorded for teamwork and support during surgery (specifically in rodents), as well as for surgical training (both in rodents (19.2%) and other mammals (14.5%)).

The quality of surgical expertise was perceived to be significantly better for non-rodent animals. Similarly, anesthetic monitoring, surgical hygiene, and teamwork

Table 4. Details about surgical practice.

Surgical practice	All, *n* (%)	Medical background* Yes, *n* (%)	No, *n* (%)
Instrument sterilization before surgery			
Yes	245 (90.1)	66 (90.4)	179 (89.9)
No	27 (9.9)	7 (9.6)	20 (10.1)
	$n = 272$	$n = 73$	$n = 199$
Instrument sterilization method			
Autoclaving	216 (79.4)	62 (84.9)	154 (77.4)
Dry heat	69 (25.4)	16 (21.9)	53 (26.6)
Gas (ethylene oxide)	21 (7.7)	8 (11.0)	13 (6.5)
Gamma radiation	6 (2.2)	4 (5.5)	2 (1.0)
	$n = 272$	$n = 73$	$n = 199$
Instrument storage			
Instrument case	220 (80.9)	64 (87.7)	156 (78.4)
Instrument pouch	172 (63.2)	54 (74.0)	118 (59.3)
Closed	83 (30.5)	26 (35.6)	57 (28.6)
Open	64 (23.5)	14 (19.2)	50 (25.1)
	$n = 272$	$n = 73$	$n = 199$
Instrument sterilization between animals in batch surgery			
Yes	98 (36.0)	25 (34.2)	73 (36.7)
No	174 (64.0)	48 (65.8)	126 (63.3)
	$n = 272$	$n = 73$	$n = 199$
Use of sterile surgical gloves			
Yes	164 (60.3)	53 (72.6)	111 (55.8)
No	108 (39.7)	20 (27.4)	88 (44.2)
	$n = 272$	$n = 73$	$n = 199$
Use of sterile personal protective equipment combined			
Yes	186 (68.4)	59 (80.8)	127 (63.8)
No	86 (31.6)	14 (19.2)	72 (36.2)
	$n = 272$	$n = 73$	$n = 199$
Routine for sterile gowning and/or gloving routine			
Yes	178 (65.4)	47 (64.4)	131 (65.8)
No	94 (34.6)	26 (35.6)	68 (34.2)
	$n = 272$	$n = 73$	$n = 199$
Fur removal			
Fur clipper	216 (79.4)	60 (82.2)	154 (75.9)
Depilation cream	71 (26.1)	27 (37.0)	44 (22.1)
Wet shave	37 (13.6)	12 (16.4)	25 (12.6)
Other (plucking, scissors, or no fur removal)	37 (13.6)	7 (9.6)	29 (14.6)
	$n = 272$	$n = 73$	$n = 199$
Surgical site preparation			
Soap	40 (14.7)	18 (32.7)	22 (12.4)
	$n = 272$	$n = 73$	$n = 199$
Alcohol	121 (44.5)	34 (46.6)	87 (43.7)
	$n = 272$	$n = 73$	$n = 199$
Skin disinfectant	213 (78.3)	62 (84.9)	151 (75.9)
	$n = 272$	$n = 73$	$n = 199$
Sterile surgical draping			
Yes	154 (56.6)	46 (63.0)	108 (54.3)
No	118 (43.4)	27 (37.0)	91 (45.7)
	$n = 272$	$n = 73$	$n = 199$
Sterile surgical instrument resting area			
Yes	137 (50.4)	38 (52.1)	99 (49.7)
No	135 (49.6)	35 (47.9)	100 (50.3)
	$n = 272$	$n = 73$	$n = 199$

(continued)

Table 4. Continued.

Surgical practice	All, *n* (%)	Medical background*	
		Yes, *n* (%)	No, *n* (%)
Perisurgical administration of antibiotics			
Yes	50 (18.4)	19 (26.0)	31 (15.6)
No	222 (81.6)	54 (74.0)	168 (84.4)
	$n = 272$	$n = 73$	$n = 199$

*DVMs and MDs are classified here as having a medical background, respondents with a degree in life sciences or other sciences—technicians and animal caretakers are not.

during surgery were perceived to be significantly better in non-rodent animals (Figure 1 suppl.).

When given the opportunity to write suggestions for improving the working conditions in free text form, the most frequently occurring words were "better," "more," and "good" regarding the workplace categories mentioned. Dedicated workspaces for surgery, new or updated equipment for surgery/anesthetic monitoring, improved hygienic conditions, dedicated and more training courses, as well as more assistance during surgery were frequently requested by survey respondents (Figure 1).

Self-efficacy. Nearly half the respondents perceived themselves as being able to elicit changes in their workplace, whereas a combined 41.6% either did not share this perception or were uncertain (Figure 2(a)). Notably, two-thirds (60.8% [54.5; 67.8]) of respondents with a medical background felt able to elicit changes, compared to fewer than half (43.6% [38.8; 48.4]) of those without a medical background. A conditional inference tree analysis revealed that respondents with surgical experience in animals outside of animal experimentation (i.e., veterinarians) had a significantly higher perception ($p < 0.001$) of being able to elicit changes in their workplace compared to respondents with either surgical experience in humans or none at all (Figure 2(b)).

Discussion

The aim of this survey was to gain insight into the respondents' surgical experience, available workplace infrastructure, and level of satisfaction with these aspects, as well as the implementation of aseptic techniques in rodent surgery.

The results of the survey confirmed that most researchers performing rodent surgery had an educational background in the life sciences (66.0%), the majority (71.5%) of whom worked in academia.[23] Veterinarians and medical doctors, consequently, represented a minority among rodent surgeons. Our data also showed that rodents, especially mice, were the predominant species on which surgeries were performed, and most surgeons performed survival surgeries. While two-thirds of researchers with a medical background also performed surgeries on other species, almost all researchers with a life sciences background performed surgeries exclusively on rodents (96.5%).

Surgeons with more professional experience, combined with a medical background, higher academic degrees, and surgical experience across different species, all correlated positively with a higher perception of being able to elicit changes in the workplace and greater confidence in improving workplace conditions. This suggests a self-awareness of professional competence and the motivation to improve conditions. In contrast, slightly less than half of the respondents were uncertain of being able to elicit changes in the workplace. Whether this was due to a lack of confidence in speaking up and voicing dissatisfaction, strictly hierarchical decision-making processes, or a deficient communication culture was not fully explored in this study and should be the subject of further inquiry. However, it is known that there is a strong correlation between self-awareness of competence/confidence in relation to improving workplace conditions and job satisfaction, and that unhappy employees are more likely to suffer from burnout or compassion fatigue.[24] Therefore, improving the competence of rodent surgeons is an integral part of fostering a good culture of care, which would not only improve animal welfare but also benefit surgeons' well-being.

While most rodent surgeons (90.1%) sterilized their instruments before surgery, only a third seemed to sterilize them between animals during batch surgery, and only half of all surgeons had a sterile instrument resting area. This could indicate either a misunderstanding or unawareness of the concept of aseptic surgery. Even if a set of sterile instruments per animal is not available during batch surgery, there are acceptable alternatives for re-sterilizing the same set of instruments between animals, such as using a hot bead sterilizer in combination with contaminating only the instrument tips ("tips only" technique) and using a sterile instrument resting area.[25] A similar situation was found in relation

(e)

Word (n = 481)	Frequency n (%)
training	38 (7.9%)
surgery	14 (2.9%)
courses	12 (2.5%)
always	9 (1.9%)
better	9 (1.9%)
surgical	8 (1.7%)
surgeon	7 (1.5%)
surgeons	7 (1.5%)
education	6 (1.2%)
student	6 (1.2%)

(f)

Word (n = 473)	Frequency n (%)
better	17 (3.6%)
surgery	14 (3.0%)
surgical	12 (2.5%)
sterile	12 (2.5%)
hygiene	9 (1.9%)
training	8 (1.7%)
aseptic	8 (1.7%)
room	7 (1.5%)
need	6 (1.3%)
rodents	6 (1.3%)

(g)

Word (n = 669)	Frequency n (%)
training	62 (9.3%)
courses	29 (4.3%)
surgery	19 (2.8%)
surgical	18 (2.7%)
practical	10 (1.5%)
education	9 (1.3%)
specific	9 (1.3%)
new	8 (1.2%)
techniques	8 (1.2%)
need	8 (1.2%)

(h)

Word (n = 353)	Frequency n (%)
surgery	10 (2.8%)
work	9 (2.5%)
assistant	7 (2.0%)
always	7 (2.0%)
training	7 (2.0%)
team	6 (1.7%)
support	6 (1.7%)
facility	6 (1.7%)
staff	6 (1.7%)
surgeon	5 (1.4%)

Figure 1. Word clouds depicting the respondents' most commonly occurring words when asked about possible improvements in surgical expertise: (a) and (e), $n = 149$; surgical hygiene: (b) and (f), $n = 156$; surgical training: (c) and (g), $n = 196$; and teamwork: (d) and (h), $n = 130$.

(a)

Impression to be able to elicit changes at the workplace	Yes	No	I don´t know	n/a
All (n = 670)	328 (49.0%)	100 (14.9%)	179 (26.7%)	63 (9.4%)
Medical background*				
Yes (n = 209)	127 (60.8%)	27 (12.9%)	52 (24.9%)	3 (1.4%)
No (n = 461)	201 (43.6%)	73 (15.8%)	127 (27.5%)	60 (13.0%)

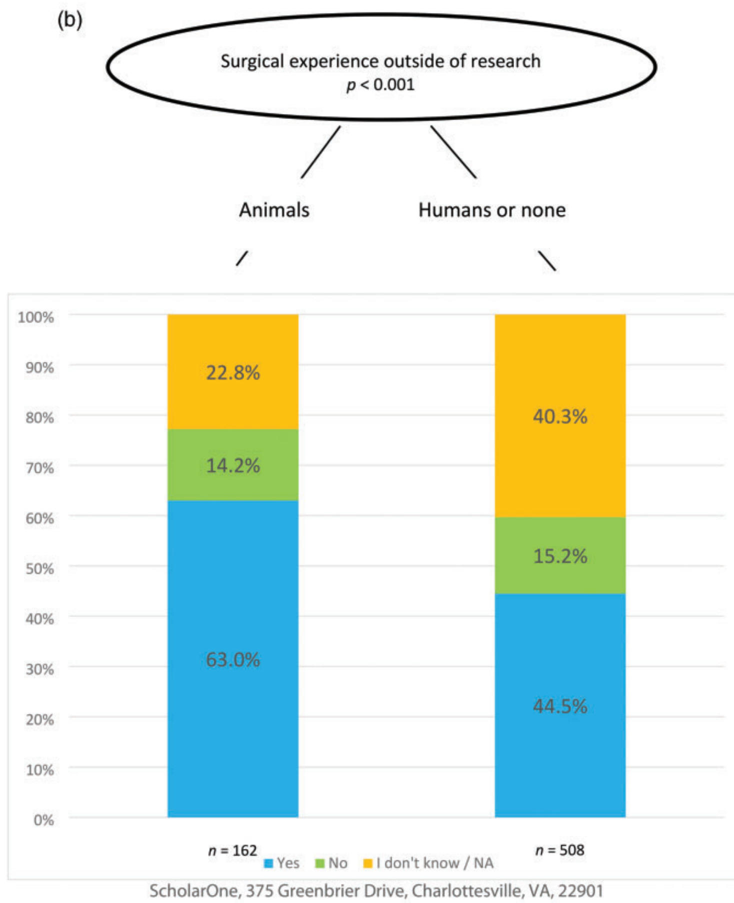

Figure 2. (a) Respondents' impressions of being able to elicit changes in the workplace; and (b) conditional inference tree highlighting significant differences in self-efficacy between survey respondents with prior surgical experience outside of laboratory animals (column labeled "Animals," $n = 162$) and those without such experience (column labeled "Humans or none," $n = 508$). $N = 670$. DVMs and MDs are classified here as having a medical background, respondents with a degree in the life sciences or other sciences—technicians and animal caretakers are not.

to the use of surgical gloves. Only around two-thirds of all rodent surgeons reported wearing sterile gloves during rodent surgery. Moreover, only 68.4% of all rodent surgeons wore a sterile gown and only 65.4% implemented a proper sterile gloving or gowning routine, further reducing the actual use of sterile gloves during surgery. This means a substantial number of surgeons do not wear sterile gloves or PPE during rodent surgery, with those from a medical background not performing substantially better than those without. Low usage of sterile drapes for the surgical patient also suggests improper aseptic working conditions during surgery, further exacerbating the situation. To the authors, these findings, and the resulting hygienic conditions, should be seen as a warning sign and an indicator of where to focus teaching and training efforts.

A single breach of the hygienic regimen can be sufficient to spread contaminants across the entire surgical site or working area. An accumulation of hygienic deficiencies can then significantly increase the risk of SSIs.[15,16] Although many laboratory rodents have a functioning, albeit untrained, immune system, researchers additionally work with genetically modified animals or disease models that might be immunocompromised.[26,27] SSIs increase morbidity and mortality, but subclinical infections can also negatively impact data quality and affect the reproducibility and translatability of study results. Consequently, heterogeneity could be observed between labs, research groups, or even animal batches.[28] As stated by Cunliffe-Beamer, “Survival alone is not a valid criterion for judgment of acceptability of a rodent surgical technique, but rather, the criterion for acceptability should be the absence of untoward, unplanned alteration of physiological functions or behavior due to perioperative infection.”[29] The surgeon’s understanding and correct application of the underlying principles of hygiene (i.e., standards for instrument care and the concepts of disinfection, sterility, and asepsis) are the foundation for good surgical practice. Therefore, surgical training should prioritize elucidating these concepts adequately.

Working in surgical teams with shared tasks offers further improvements, especially for batch surgeries where managing perisurgical tasks can occupy a significant amount of working time and disrupt an aseptic workflow. While teamwork is commonplace in larger animal species and in humans, there is still a significant lack of assistance in rodent surgeries. Especially when considering the previously discussed hygienic insufficiencies in rodent surgery, the lack of a perceived need for assistance among survey respondents is difficult to understand. Whether this is due to a misunderstanding of the principle of asepsis, an overconfidence in one’s own skills, or another reason altogether was not addressed in the conducted survey.[30] Nevertheless, more dedicated surgical training was one of the most requested subjects when asked about potential improvements to workplace conditions and surgical expertise, with the need for additional training mentioned across multiple categories (Figure 1). While there appears to be a strong motivation to enhance surgical knowledge and undertake practical skills training, dedicated courses are scarce, expensive, and may require long-distance travel. Establishing a mandatory training program would be an important tool to promote good surgical practices and improve the quality of animal care during experimental surgery across all species.[31] In addition, the specific challenges of rodent surgery—such as microsurgery, magnification, and batch surgery—should be integrated into rodent-specific training courses. Furthermore, an operating room committee should be established to review the existing infrastructure and establish institutional guidelines.[31]

Mandatory, basic introductory courses in animal experimentation (FELASA Function A) do not sufficiently prepare researchers to perform surgery safely and successfully. A combined effort from all sides is needed to improve the current state of hygiene in rodent surgery and to overcome the obstacles we have identified. Guidelines, ideally complemented by video tutorials, should be harmonized and made freely available for easier access to learning materials. Refresher training and/or regular self-assessments, similar to those that are mandatory for human medical doctors, should be considered.[32,33] Expert societies and conferences could further promote good surgical practice in the field and foster networking across professional bubbles.

One major limitation of this survey was the recruitment of respondents. By sending out invitations via professional societies in the field of laboratory animal sciences, a potential selection bias in the population sample cannot be ruled out. Furthermore, survey return rates could not be calculated due to data protection regulations. The data showed that most survey respondents worked in Switzerland (47.7%), followed by respondents from Germany (13.2%), the UK (10.8%), and France (7.2%) representing the countries that used the most laboratory rodents in Europe.[1] Here, we can see a notable bias toward respondents from Switzerland, most likely due to the relative ease of recruiting colleagues known to the authors. Nonetheless, we hypothesize that rodent surgeons based in Switzerland are not significantly different from their peers in other countries. Moreover, the majority of respondents were affiliated with academia, which may be attributable to confidentiality constraints, leading to an underrepresentation of colleagues working in industry. Overall, the respondents showed a broad variation in terms of age, nationality, educational background, and degree, with roughly equal numbers of male and female respondents. Therefore, we assume that we captured a representative picture without missing a major group of stakeholders. However, the relatively high number of rodent surgeons working in this field for over 10 years (50.5%) does not necessarily reflect the average, and could be linked to the distribution strategy of survey invitations.[23]

Finally, it must be pointed out that the true cost of losing a surgical patient exceeds the mere costs of animals and consumables. Time efforts, experimental scheduling, ethical considerations, and the emotional burden on the surgeon should also be taken into account. Moreover, performing surgeries after undergoing proper surgical training not only improves animal welfare and data quality but also increases the surgeons’ confidence in their own skills and raises the level of job satisfaction.[24]

In conclusion, training for rodent surgery should be tailored to the surgeon’s preexisting knowledge, skill level, and experience. Based on the findings of this study, we suggest that additional surgical training be made mandatory before performing surgery on laboratory animals, including rodents, to ensure the highest standards of animal welfare.

Author contributions

The authors confirm contribution to the paper as follows: study conception and design: FG, SH, SZ, PS; data collection: FG, SH, SZ, PS; analysis and interpretation of results: FG, SH, SZ, PS; draft manuscript preparation: FG. All authors reviewed the results and approved the final version of the manuscript.

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Supplementary material

Supplemental material for this article is available online.

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Chirurgies chez les rongeurs – qui les effectue et comment?

Résumé

La chirurgie fait partie intégrante de nombreuses études expérimentales. Une bonne pratique chirurgicale est une condition préalable à la réussite chirurgicale ainsi qu'au bien-être optimal des animaux. Elle améliore non seulement la récupération post-opératoire, mais aussi le résultat global et la validité d'une étude. Les rongeurs – en particulier les souris – sont les animaux de laboratoire les plus couramment utilisés et les exigences légales pour procéder à une chirurgie expérimentale sont identiques pour toutes les espèces. Les exigences minimales en matière de formation chirurgicale varient toutefois considérablement d'un pays à l'autre, allant de simple cours d'initiation à l'expérimentation animale à des formations supervisées et avancées dirigées par des chirurgiens experts, ce qui complique les efforts de normalisation. Cette étude fournit un aperçu de la formation et de l'expérience en chirurgie, de l'infrastructure disponible, de la satisfaction en milieu de travail et de l'application de bonnes pratiques chirurgicales dans le cadre des interventions pratiquées sur des rongeurs en laboratoire. Deux enquêtes en ligne comportant 72 questions ont été distribuées à travers l'Europe. 782 réponses complètes ont ensuite été reçues et analysées. Les résultats montrent que la plupart des chercheurs pratiquant des interventions chirurgicales chez les rongeurs n'ont aucune formation médicale. En outre, les bonnes pratiques chirurgicales (blouse et port de gants stériles, décontamination et drapage de l'animal et utilisation de matériel stérile) semblent mal appliquées lors des interventions chirurgicales effectuées sur des rongeurs. La moitié de tous les chirurgiens utilisant des rongeurs n'ont en outre aucune aide disponible et la plupart des répondants ont exprimé un désir de formation continue et de cours pour approfondir et perfectionner leurs compétences chirurgicales. La formation à la chirurgie des rongeurs devrait donc être adaptée aux connaissances préexistantes du chirurgien et une formation chirurgicale supplémentaire devrait être rendue obligatoire avant de pratiquer toute chirurgie sur des rongeurs de laboratoire. Cela pourrait améliorer non seulement le bien-être des animaux mais aussi celui des chirurgiens.

Operationen an Nagetieren – von wem und wie werden sie durchgeführt?

Abstract

Chirurgie ist ein integraler Bestandteil vieler experimenteller Studien. Eine gute chirurgische Praxis ist eine Voraussetzung für den chirurgischen Erfolg und optimales Tierwohl. Sie verbessert nicht nur die postoperative Genesung, sondern auch das Gesamtergebnis und die Aussagekraft einer Studie. Nagetiere – insbesondere Mäuse – sind die am häufigsten verwendeten Labortiere, und die gesetzlichen Anforderungen für die Durchführung von experimenteller Chirurgie sind für alle Tierarten gleich. Die Mindestanforderungen an die chirurgische Ausbildung sind jedoch von Land zu Land sehr unterschiedlich – sie reichen von grundlegenden Einführungskursen in Tierversuche bis hin zu fortgeschrittenen Kursen, die von erfahrenen Chirurgen geleitet werden – was die Bemühungen um eine Standardisierung erschwert. Diese Studie gibt Aufschluss über die chirurgische Ausbildung und Erfahrung, die verfügbare Infrastruktur, die Zufriedenheit am Arbeitsplatz und die Anwendung guter chirurgischer Praxis in der Chirurgie von Labornagern. Zwei Online-Umfragen mit insgesamt 72 Fragen wurden in ganz Europa durchgeführt. Es gingen 782 vollständige Antworten ein, die ausgewertet wurden. Die Ergebnisse zeigen, dass die meisten Forscher, die chirurgische Eingriffe an Nagetieren vornehmen, keinen medizinischen Hintergrund haben. Darüber hinaus scheint eine gute chirurgische Praxis (d. h. sterile Kleidung und Handschuhe, Dekontaminierung und Abdecken des Patienten und Verwendung steriler Ausrüstung) in der Nagetierchirurgie nur unzureichend umgesetzt zu werden. Außerdem steht der Hälfte aller Nagetierchirurgen keine Assistenz zur Verfügung, und die meisten Befragten äußerten den Wunsch nach kontinuierlicher Weiterbildung und Kursen zur Vertiefung und Optimierung ihrer chirurgischen Fähigkeiten. Dementsprechend sollte die Ausbildung für die Chirurgie an Nagetieren auf die bereits vorhandenen Kenntnisse des Chirurgen zugeschnitten sein, und eine zusätzliche chirurgische Ausbildung sollte vor der Durchführung von Operationen an Labornagern obligatorisch sein. Dies könnte sich sowohl auf das Wohlergehen der Tiere als auch auf das der Chirurgen positiv auswirken.

Cirugías en roedores: ¿quién las realiza y cómo?

Resumen

La cirugía es una parte fundamental de muchos estudios experimentales. Una buena práctica quirúrgica es un requisito previo para el éxito quirúrgico y el bienestar de los animales, y no solo mejora la recuperación postoperatoria sino también el resultado global y la validez de un estudio. Los roedores, especialmente los ratones, son los animales de laboratorio más utilizados y los requisitos legales para realizar cualquier cirugía experimental son idénticos para todas las especies. No obstante, los requisitos mínimos de formación quirúrgica varían significativamente de un país a otro, desde cursos básicos de introducción a la experimentación animal hasta cursos avanzados y supervisados dirigidos por cirujanos expertos, lo que complica los esfuerzos para conseguir una estandarización. Este estudio proporciona información sobre la formación y la experiencia quirúrgicas, la infraestructura disponible, la satisfacción en el lugar de trabajo y la aplicación de buenas prácticas quirúrgicas a la hora de llevar a cabo cirugías con roedores de laboratorio. Se distribuyeron por toda Europa dos encuestas en línea con un total de 72 preguntas y se recibieron 782 respuestas completas que fueron analizadas con posterioridad. Los resultados demuestran que la mayoría de los investigadores que realizan cirugías en roedores no tienen formación médica. Asimismo, una buena práctica quirúrgica (como el uso de batas y guantes estériles, la desinfección y el cubrimiento del paciente y el uso de equipo estéril) parece estar pobremente implementada en las cirugías con roedores. Por otro lado, la mitad de los cirujanos de roedores no disponen de asistencia y la mayoría de los encuestados expresaron su deseo de recibir formación continua y cursos para profundizar y perfeccionar sus habilidades quirúrgicas. Por ello, la formación para la cirugía de roedores debería adaptarse a los conocimientos preexistentes del cirujano y debería ser obligatoria una formación quirúrgica adicional antes de realizar intervenciones quirúrgicas en roedores de laboratorio. Esto podría mejorar tanto el bienestar de los animales como el de los cirujanos.