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ORIGINAL RESEARCH

Surveying UK sheep farmers' vaccination techniques and the impact of vaccination training

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Abstract

Background: Vaccines are commonly used in sheep farming. However, compliance with vaccination protocols and subsequent suboptimal vaccination techniques are concerns in the industry.

Methods: An online survey containing 31 questions encompassing vaccination storage, technique and training was distributed to UK sheep farmers. Respondents were asked to mark on a sheep diagram where they would administer intramuscular (IM), intradermal, and subcutaneous (SC) vaccines.

Results: Of 370 respondents, only 26.1% identified the correct location for SC, 38.0% for intradermal, and 7.7% for IM vaccination. Almost half (45.5%) stored their vaccines in a fridge specific to veterinary medicines, only 33.9% used a temperature logger, and 6.4% checked their fridge temperature daily. Almost half (45.5%) kept their vaccines 48 hours or longer after broaching, and 11.1% kept them until the next time. Significantly more respondents who had received training correctly identified the location for IM vaccination ($p < 0.01$). However, training had no significant influence on the the correct identification of the other vaccination sites, vaccine storage or administration.

Conclusion: Suboptimal vaccination techniques are not due to unwillingness to learn; 83.8% responded that they would consider taking a course to improve their use. However, the majority (73.9%) were unaware of the training courses available. Therefore, the industry needs to respond and promote courses.

INTRODUCTION

Veterinary vaccines, widely used since the 1700s, are a vital component in protecting the health and welfare of both individuals and flocks. This is achieved through controlling, protecting from, and eradicating disease, thus supporting the sheep industry's financial viability.[1,2] Vaccine effectiveness depends on following the correct administration procedures (both route and location) and maintaining the cold chain; otherwise, investment is wasted, and animal welfare and efficacy are reduced.[3,4]

UK sheep vaccinations are administered by those deemed capable by the person prescribing them. This would be either a veterinarian, pharmacist or a suitably qualified person (SQP) (also known now as a Registered Animal Medicines Advisor [RAMA]). However, concerns are present that farmers are using incorrect vaccine protocols. Small et al.[4] showed that numerous of their study's 586 sheep farmers mis-administered the orf vaccine (Scabivax Forte, MSD Animal Health, Milton Keynes, UK) in terms of location (27% correct), site cleanliness (25%) and having a temperature logger in the fridge (26%). The researchers speculated that these shortcomings might affect the efficacy of the given vaccine. A separate study ($n = 762$) showed that only 8% of the total farms followed the advised protocol for orf vaccination.[5] Findings in cattle highlighted areas of suboptimal vaccination techniques, including injection site and needle hygiene.[6] Although caution is appropriate when comparing across species, mis-administration of other sheep vaccines is entirely plausible.

While most sheep vaccines are administered subcutaneously or intramuscularly, the orf vaccine is administered intradermally in the axilla.[7] Datasheets

state the preferred site for subcutaneous (SC) injection as the caudolateral neck region.[8,9] Contradictions can exist between different literature, as well as between literature and datasheets.[10] Intramuscular (IM) vaccination is advised into the neck.[11–13] Other areas, such as the rump and quadriceps, are mentioned on online platforms.[12] However, injecting into the quadriceps could be economically detrimental, risking damaging valuable cuts of meat.[10]

Most abscesses in sheep are avoidable. However, 1.9% of sheep carcasses (176,500) showed abscessation. An incorrect injection technique or contaminated needles is regarded as the most likely cause.[11] Abscessation must be excised, reducing meat yield and quality, devaluing prime cuts, or resulting in whole carcass downgrade, reducing profitability.[14] Repeated use of needles may also result in these outcomes as well as pain, injection site blemishes, iatrogenic transmission of disease and broken needles.[15–17]

Poor vaccination techniques in cattle are linked to iatrogenic sciatic nerve damage when injected into the gluteal muscle.[18] Further work is needed to confirm whether hindlimb IM injection in sheep may cause similar iatrogenic nerve damage based on injection site location.

Knowledge of vaccination techniques is important for veterinarians to understand as key communicators and suppliers of vaccines.[4,19] Cresswell et al.[6] identified the need to understand how farmers were trained in bovine vaccination. However, no subsequent studies appear to address this in cattle or sheep.

Thus, this study aims to develop an understanding of the knowledge of and training in vaccination techniques in UK sheep farmers and to establish whether there is a link between correct vaccination techniques and training. The study's findings can be used to assess whether training opportunities are adequate and in the required format, leading to improved advice and training, vaccination success, animal welfare, and economic output.

MATERIALS AND METHODS

An online survey using a semi-structured questionnaire was developed and was open from 14 February to 21 June 2021. An online approach was chosen for maximum geographic coverage and participant convenience.

Alchemer (https://app.alchemer.eu), a survey platform, was used to develop and distribute the survey. The target population was UK sheep farmers; only those involved or who worked with sheep and vaccinated their flock were asked to answer.

The questionnaire contained 31 questions (open [n = 1] and closed [n = 30]) with demographic questions (n = 7/31) at the end. Sixteen of the 31 questions were related to their flock or farm they worked with, vaccine purchases and vaccination technique (site of administration, vaccine hygiene, storage and disposal). Eight questions were related to training and confidence. The correct vaccine protocols were sourced from the vaccine datasheets.[7–9,13,20–27] All sheep vaccines registered in the UK were included. Two imported vaccines were added due to UK use (Barbervac and Glanvac 3). The Schmallenberg and Bluetongue vaccines were excluded, as they were not available in the market at the time. Multiple answers could be selected for seven questions; therefore, the reported percentages may exceed 100%.

Definitions were created for correct location and correct use/storage from the datasheets (Table 1). Figure 1a is used to establish the coordinates.[11] Additionally, for IM injection, an overlay of meat cuts described by a butcher was placed onto the original sheep image to count respondents in each area (Figure 1b).

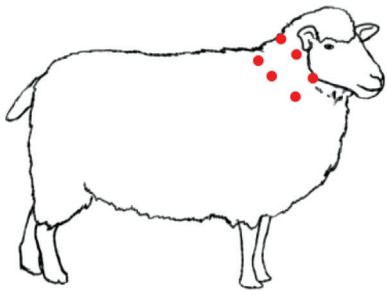
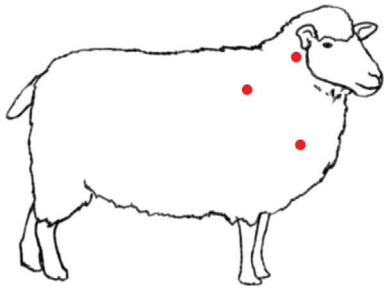
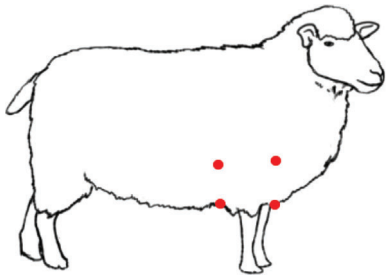
Mobile fish (www.mobilefish.com) was used to plot individual coordinates and establish if the individual's response was within the correct coordinates. Similarly, the overlay in Figure 1b was performed using this program. Rather than one singular point (Figure 1a), a larger coordinate area than would be expected was selected. This approach attempted to account for variation in the interpretation of the images. Participants' responses were also considered correct if there was correct use/storage (according to the vaccine datasheet): storing the vaccine at fridge temperature, discarding unused vaccine on the day of broaching, having a temperature logger or checking the temperature daily.

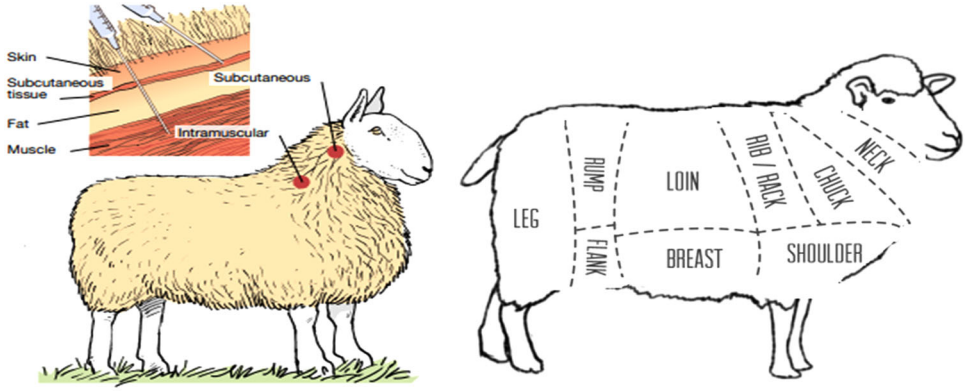
The survey was piloted on five individuals within the sheep industry. The survey began by stating the rationale, the target population, and a time scale for completion (5–10 minutes). All data were kept anonymous, and participants' anonymity was maintained and stored securely, in accordance with the UK Data Protection Act 2018/GDPR (general data protection regulation). By completing the questionnaire, the participant gave consent for their responses to be analysed. Ethical approval was given by the Social Science Research Ethical Review Board, Royal Veterinary College (URN SR2020-0334). The objective of this study was to develop an understanding of the knowledge of and training in vaccination techniques in UK sheep farmers.

Distribution

Using a convenience sampling method, a link to the online survey was used as a distribution method for participation or forwarding. The link was posted on the British Farmers forum (6256 members), Farmers forum (51,880 members), in the newsletter of the National Sheep Association (4000 sheep farmers), and via online social media (Facebook and Twitter). Completion was voluntary. Both completed and partial responses were retained.

TABLE 1 Coordinates used to identify the 'correct location' for subcutaneous, intramuscular and intradermal vaccines

Vaccination type	Correct location	Incorrect locations	Coordinate values	Location on diagram
Subcutaneous	Upper neck region, 2–3 in. behind the ear (8)	Over the ribs (not described on the datasheet for subcutaneous vaccines)	(277,36) (262,58) (320,68) (298,93) (291,51) (275,73)	
Intramuscular	Neck muscles (7) A triangle running below the ear to the shoulder should be formed (12)	Rump and mid-lower leg (hindlimb) considered incorrect due to the trend to vaccinate away from these areas and not stated on the datasheet	(300,56) (304,142) (252,88)	
Intradermal	Behind the elbow, in the hairless skin of the axilla is the recommended site (7)	Hindleg, neck, tail, or other location on/off the animal	(225,208) (223,168) (279,164) (278,209)	



(a) (b)

FIGURE 1 (a) Correct location of both intramuscular and subcutaneous injection (ADHB 2018) and (b) overlay on original sheep diagram to locate the cuts of meat that would be injected into

Statistical analysis

The data set was exported to Microsoft Excel 2016 and filtered before imputing to SPSS (IBM). Cross-tabulation tables were formed to determine the significance between correct location and correct use/storage and those who had undertaken training or been on a course (<5 years). Cross-tabulation tables were used to perform chi-squared tests on variables. Statistical significance was considered if $p < 0.05$. The coordinates generated (heatmap diagrams) were plotted using Mobile fish to map each response and determine if this was correct. For all of the data presented, the percentage of the total may exceed the total response when multiple responses were permitted (the numerator may be greater than the denominator).

TABLE 2 Demographic information about the respondents' farms

Demographic	Categories	% (*n*)
Size of flock, *n* = 273	<50	15.4 (42/273)
	51—499	45.4 (124/273)
	500+	22.3 (61/273)
	1000+	16.8 (46/273)
Type of holding, *n* = 274	Commercial sheep only	25.9 (71/274)
	Commercial sheep + arable	6.9 (19/274)
	Commercial sheep + cattle	35.4 (97/274)
	Commercial sheep + cattle + arable	13.5 (37/274)
	Small holder	13.1 (36/274)
	Other	5.1 (14/274)
All flock vaccinated or part, *n* = 273	All	94.1 (257/273)
	Part (total)—categorised below	5.9 (16/273)
	Vaccinating all breeding ewes only	2.2 (6/273)
	With regard to farm-specific problems	1.1 (3/273)
	Vaccinating all lambs	1.1 (3/273)
	Vaccinating pre-tupping	0.4 (1/273)
	Nonspecific	1.1 (3/273)

RESULTS

Survey response

There were 370 responses (216 complete and 154 partial). Both complete and partial data were included. Of the 273 respondents who answered, 94.1% vaccinated all of their flock, the remaining 5.9% vaccinated part of their flock.

Under half of the respondents (45.4%, *n* = 124/273) had a flock size of 51–499. Businesses ranged from small holders (13.1%, *n* = 36/274) to commercial enterprises (Table 2).

Demographic distribution

The majority of respondents had more than 20 years of experience in the sheep industry (60.7%, 130/214), with most being a partner/owner of the farm (68.5%, 146/214). Sixty-one percent were male, with a wide age range between 20 and 50 years (60.6%, 129/213) (Table 3). Respondents were geographically dispersed throughout the UK (Figure 2).

Vaccination use and purchase on the farm

The majority of respondents purchased their vaccines from an agricultural merchant (66.8%, 179/268), and 29.1% (78/268) purchased from their veterinarian (Table 4). A minority (43.7%, 117/268) had received training in vaccination technique defined as training in administration, storage, location of injection, and vaccine hygiene. The time period for when training was received was not defined and could be verbal or on

TABLE 3 Demographic information about questionnaire respondents

Demographic	Categories	% (*n*)
Gender, *n* = 214	Male	60.7 (130/214)
	Female	37.4 (80/214)
	Prefer not to say	1.9 (4/214)
Age, *n* = 213	20 or under	0.5 (1/213)
	21—30	17.7 (37/213)
	31—50	44 (92/213)
	+51—70	37.8 (79/213)
Level of education, *n* = 214	School education	13.1 (28/214)
	Further education[a]	35.0 (75/214)
	Higher education[b]	51.9 (111/214)
Length of time working with sheep, *n* = 214	<2 years	0.9 (2/214)
	2–5 years	5.6 (12/214)
	5 years +	12.1 (26/214)
	10 years +	20.6 (44/214)
	20 years +	23.8 (51/214)
	30 years +	36.9 (79/214)
Role on the farm, *n* = 213	Partner/owner	68.5 (146/213)
	Manager	2.3 (5/213)
	Shepherd	5.6 (12/213)
	Tenant	4.78 (10/213)
	Worker	2.8 (6/213)
	Family/family business	14.6 (31/213)
	Other	1.4 (3/213)

[a]Any education after secondary school that is not an undergraduate or postgraduate degree, for example, college, apprenticeship.
[b]Undergraduate or postgraduate qualification.

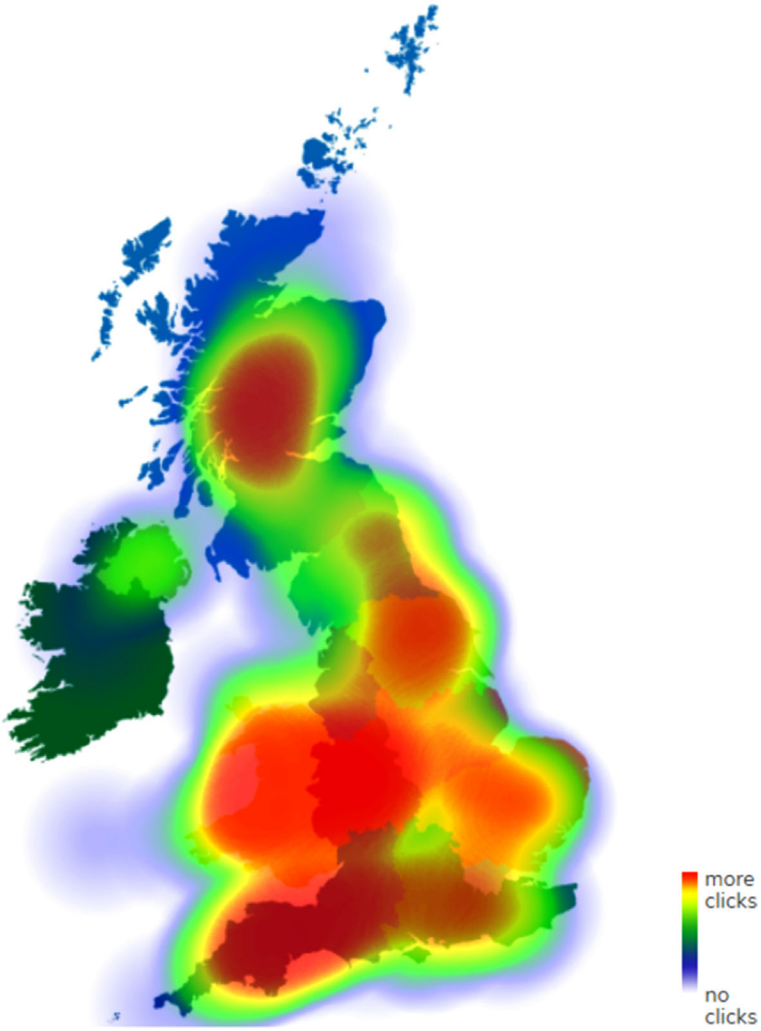


FIGURE 2 Heatmap of geographic spread of participants

a course. Expanding on their training, responses could be categorised into the following (Table 5).

Nearly half of 268 respondents (48.1%, 129/268) learned to vaccinate from their veterinarian, closely followed by a family/friend/neighbour (44.4%, 119/268). Only 10.1% (27/268) learned to vaccinate from their farm merchant (SQP), despite respondents mostly purchasing their vaccines from them (Table 6). A majority (95.5%, 231/242) of the respondents were vaccinated against clostridial diseases on the farm. A minority vaccinated against lameness (30.6%, 74/219) and orf (19.4%, 47/242). Most (63.9%, 85/133) respondents did not change their flock routine prior to vaccinating them (Table 7).

Vaccine administration and hygiene

There was a wide variation in the data points when respondents indicated where they would inject a SC, IM, and intradermal vaccine (Figures 3–5).

Subcutaneous vaccine location

SC responses mapped to two generalised areas, the neck and a distribution over the ribs. The correct location is the lateral side of the upper neck; in some of the datasheets, 2–3 cm behind the ear is also mentioned.[8,13] Twenty-six percent of participants identified the correct location (Figure 3) (26.1%, 80.9/310). There was no significant difference between those who had received training and those who clicked within the right location ($p = 0.194$) (Table 8).

Intramuscular vaccine location

Two defined areas were highlighted: the neck (29% of responses) and the leg region (60% of responses). Only 14% of respondents clicked within the correct coordinates (Figure 4). There was a significant difference between those who had received training and those who chose the correct location (Table 9). With regard to the location of injection, in general, most were in the upper leg/rump (Table 10).

Intradermal vaccine location

A lower response rate was noted for this question ($n = 219$). Thirty-eight percent of participants were within the region of the only correct location (38%, 83.2/219) (Figure 5). There were clusters in three other

TABLE 4 Vaccination use and purchase on farm

Question	Category	% (*n*)
From whom are vaccines mostly purchased? ($n = 268$)	Veterinarian	29.1 (78/268)
	Agricultural merchant (SQP)	66.8 (179/268)
	Pharmacist	1.1 (3/268)
	Internet pharmacist	2.2 (6/268)
	Other	0.7 (2/268)
Farmer has been trained in vaccination technique—yes/no ($n = 268$)	Yes	43.7 (117/268)
	No	56.3 (151/268)
What vaccines are used on farm? ($n = 242$)[a]	Clostridial diseases (Heptavac P Plus, Ovivac P Plus, Lambivac, Covexin 10, Covexin 8, Bravoxin 10, Blackleg only vaccine)	95.5 (231/242)
	Pasteurellosis (Heptavac P Plus, Ovipast Plus, Ovivac P Plus)	63.6 (154/242)
	Sheep abortion (Enzovax)	31.4 (76/242)
	Sheep abortion (CEVAC Chlamydia)	16.9 (41/242)
	Sheep abortion (Toxovax)	36 (87/242)
	Foot rot (Footvax)	30.6 (74/242)
	Orf (Scabivax Forte)	19.4 (47/242)
	Haemonchus (Barbervax 'imported')	0.4 (1/242)
	Johnes (Gudair Vaccine Virbac)	2.5 (6/242)
	Caseous lymphadenitis (Glanvac 3 Zoetis 'imported')	0.4 (1/242)
	Mastitis (Vimco Mastitis Vaccine)	1.2 (3/242)
	I do not know	0.4 (1/142)
What instructions do you follow when you vaccinate? ($n = 235$)[a]	On the box/bottle	71.1 (167/235)
	On the datasheet	71.1 (167/235)
	I follow instructions on the dispensing label	25.5 (60/235)
	I follow verbal instructions from my vaccine supplier	18.3 (43/235)
	I do what I have done previously	9.4 (22/235)
	Other	2.6 (6/235)

[a]Multiple answers could be selected, and therefore, proportions may exceed 100%.
Abbreviation: SQP, suitably qualified person.

areas: around the hindlimb (35%), the tail (6%) and the neck region (15%). Of respondents who were placed within the red zone near the front limb, 21% of participants were within the coordinate set boundaries and deemed 'correct' (Figure 5). There was no significant difference found between those who had training previously and been on a training course within the last 5 years and those who selected correctly (Table 11).

A minority (21.9%, 48/219) vaccinated against orf (the only intradermal vaccine); however, of those who did, 29.2% were within the correct region of the forelimb, and only 14.6% were within the correct coordinates (Figure 6). There was no significant difference between those who vaccinate against orf versus those who did not and were within the correct coordinates ($p = 0.518$).

Respondents were asked to rank how often they did the following in Figure 7 to gain an understanding of their knowledge around vaccinating and good vaccinating techniques.

The majority never wore gloves when vaccinating (46.9%, 105/224), but a similar number always washed their hands before and after vaccinating (46.5%, 105/226). A minority (3.3%, 7/212) of respondents would change their needle after every animal. Few would always change their needle after 15–20 doses (20.3%, 44/217), 32.4% (66/204) would always change the needle after 50 doses, while 39.5% (75/225) would always change their needle after 100 doses. The majority (94.4%, 219/232) answered to say they store their vaccines according to the datasheet.

Vaccine storage and discard

The vaccine datasheets recommend that most unused vaccines should be discarded between 8 and 10 hours on the day of broaching.[7–9,13,21–27] Just over half 54.5% (128/235) adhered to this. Other respondents would keep the vaccine to be used on an alternative day. A large minority, 45.4% (100/221), stored their vaccines in a specific veterinary medicine fridge with 33.9% (74/218) having a temperature logger. Only 6.4% checked the temperature of their fridge daily. Most knew to store the vaccines at fridge temperature (96.4%, 212/220). There was no significant difference between those who had received training in the last 5 years and those who stored and discarded their vaccines correctly (Table 12).

TABLE 5 Participants' open question responses when asked to state training that had been received

Response category	% (*n*)
At agricultural college	22.2 (26/117)
Advice and guidance from vets	21.4 (25/117)
Course ran by our vets	6.8 (8/117)
Through ADHB	0.9 (1/117)
I am a veterinarian	7.7 (9/117)
I am a veterinary nurse	2.6 (3/117)
I am a veterinary student	2.6 (3/117)
As part of farm assurance	2.6 (3/117)
By reading training guidance in National Sheep Association publications	0.9 (1/117)
City and guilds qualification in recording and administering medicines to farm animals	1.7 (2/117)
As part of SQP training	3.4 (4/117)
By an SQP	1.7 (2/117)
By DEFRA	0.9 (1/117)
National Proficiency Test Council (NPTC) safe use of vet med cert	1.7 (2/117)
From family member	1.7 (2/117)
Safe use of medicines course	0.9 (1/117)
Red Tractor medicine course	2.6 (3/117)
Did not expand on their answer	15.4 (18/117)
By reading manufacturers' datasheets	2.6 (3/117)

Note: Not all participants in the survey answered (the total number of responses to the open question was 117).
Abbreviation: SQP, suitably qualified person.

TABLE 6 Survey results for the question 'How or from whom did you learn to vaccinate?'

Response	% (*n*)
Work colleague	22.8 (61/268)
Boss	16.0 (43/268)
Veterinarian	48.1 (129/268)
Family/friend/neighbour	44.4 (119/268)
Suitably qualified person—farm merchant	10.1 (27/268)
Pharmacist	0.4 (1/268)
Publications, for example, farmers weekly/farmers guardian, etc.	6.3 (17/268)
Responsible Use of Medicines in Agriculture (RUMA) guidelines	2.2 (6/268)
On a course (detailed in Table 5)	13.8 (37/268)
Online other	2.2 (6/268)
Other	8.2 (22/268)

TABLE 7 Categorised answers to whether the participants changed their flock routine prior to vaccinating

Response category	% (*n*)
No change	63.9 (85/133)
When footvaxing, sheep were moved onto a concrete area as they were footbathed at the same time	0.8 (1/133)
Avoid stress before and after vaccinating	12 (16/133)
Vaccinating when moved	6.8 (9/133)
In lamb ewes were vaccinated when home for lambing	0.8 (1/133)
Feed before vaccinating if pregnant	0.8 (1/133)
Make sure dry if possible	3 (4/133)
Housed the night before or as long as it takes them to dry	0.8 (1/133)
Moved closer to the yard	0.8 (1/133)
Minimal yarding/holding time	0.8 (1/133)
Moved to handling facilities	6 (8/133)
Did not specify	3.8 (5/133)

Vaccine confidence and training

Most of the respondents 'strongly agreed' (37.2%, 83/223) or 'agreed' (55.2%, 123/223) that they understood how vaccines worked (Figure 8), and the majority felt they were confident in the location on the animal they should be injecting, 56.1% (125/223) 'agreed' and 37.2% (83/223) 'strongly agreed'. The majority of respondents also felt confident in effective vaccination techniques (92.4%, 205/222) and knew whom to contact regarding vaccine advice (93.3%, 208/223).

Thirty percent of respondents had been on a training course within the last 5 years and were asked to state the course. The answers were categorised (Table 13). When asked if the respondent was aware of any training courses available, a minority answered yes (26.1%, 57/218).

A majority of respondents (83.9%, 182/217) would consider going on a course in person or online to improve their knowledge of the safe use of medicines. Few respondents were aware of training courses that they could attend (26.1%, 57/218). There were four main barriers to training (Table 14), which were time (45.6%, 93/204), money (35.8%, 73/204), awareness of existing courses (34.8%, 71/204) and feeling they already had the knowledge to vaccinate safely and effectively (40.7%, 83/204).

DISCUSSION

This study confirms that suboptimal vaccination techniques are being carried out on UK farms. This is of concern, as it may affect vaccine efficacy, lower the price per head of the animal and result in a higher prevalence of disease. The majority of farmers thought they were confident in the vaccination technique. Nonetheless, the results show that a majority improperly administer or store vaccines. These results suggest

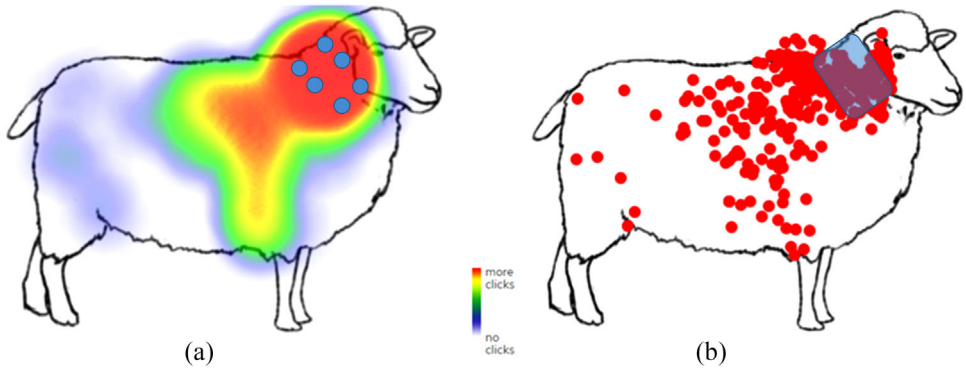


FIGURE 3 Heatmap (a) of respondents' answers when asked to mark on the diagram the location of where they would choose to inject a subcutaneous vaccine ($n = 310$, multiple clicks were permitted). Distribution of individual points (b). The percentage of participants locating the correct location within the correct coordinates was 26.1%, indicated by blue dots/shaded area

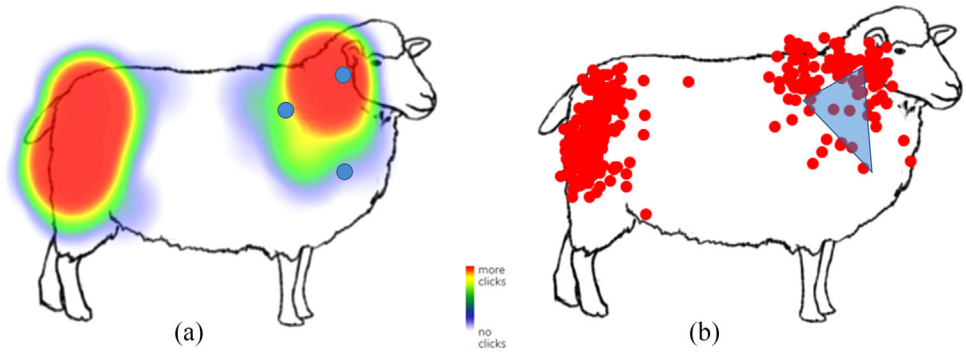


FIGURE 4 Heatmap (a) of respondents' answers when asked to mark on the diagram the location of where they would choose to inject an intramuscular vaccine ($n = 299$) (multiple clicks were permitted). (b) Individual distribution of the location chosen for anintramuscular vaccine. Correct coordinates blue dots/shading

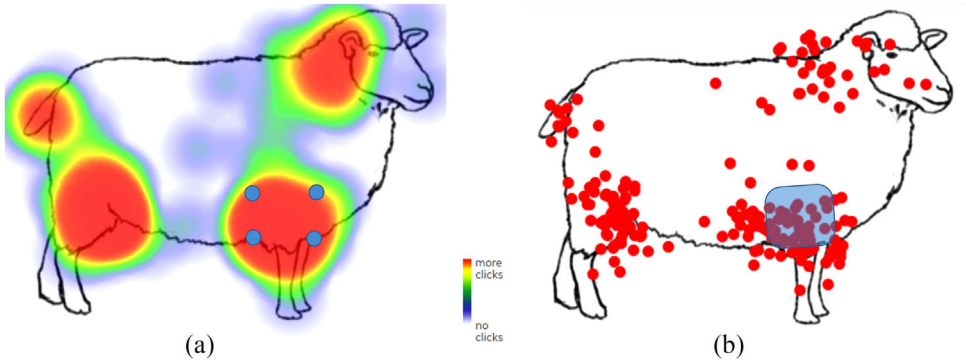


FIGURE 5 Heatmap (a) of respondents' answers when asked to mark on the diagram where they would choose to inject an intradermal vaccine. (b) Individual distribution of the location chosen for an intradermal vaccine. Correct coordinates blue dots/shading

TABLE 8 Survey response to training versus correct vaccination location for all sites

	Category	% (*n*)	Correct location for the subcutaneous vaccine within coordinates, % (*n*)	Significance
Did the individuals have training at some point (not defined)?	Yes No	43.7 (117/268) 56.3 (151/268)	32 (10/310) 15 (48/310)	$p = 0.194$
Have the individuals been on a training course within the last 5 years?	Yes No	30 (65/217) 70 (152/217)	0 (0) 26 (80/310)	NA, no individuals had been on a course that had correct location

TABLE 9 Survey response to training versus correct intramuscular vaccination location

	Category	% (*n*)	Correct location for the intramuscular vaccine within coordinates, % (*n*)	Significance
Did the individuals have training at some point (not defined)?	Yes	43.7 (117/268)	6.7 (20/299)	$p < 0.01$
	No	56.3 (151/268)	1 (3/299)	
Have the individuals been on a training course within the last 5 years?	Yes	30 (65/217)	4.4 (13/299)	$p = 0.002$
	No	70 (152/217)	3.4 (10/299)	

TABLE 10 Percentage of respondents ($n = 299$) (multiple options were permitted) who would inject an intramuscular injection into each location (considered by the cut of meat)

Location	% (*n*)
Neck	25.7 (77/299)
Upper leg/rump	32.8 (98/299)
Leg	27.1 (81/299)
Rib	8 (24/299)
Rump (termed by butchers cut)	2.3 (7/299)
Head	2.7 (8/299)
Shoulder	0.3 (1/299)
Flank	0.3 (1/299)
Loin	0.3 (1/299)
Off image	0.3 (1/299)

Note: Into the neck is considered the gold standard.

a disparity between farmers' self-reported confidence and actual administration of vaccines.

Positioning of intradermal, subcutaneous, and intramuscular vaccinations

IM vaccinations are specified on drug datasheets as the lateral side of the upper neck, indicated by a small minority in this study (7.7%). The neck site, chosen for trials, is likely due to a lower value cut of meat and risk of injection site lesions (ISL), which results in downgrading of meat.[11,14] Subsequently, the neck becomes ingrained in the datasheets of many of the vaccines, resulting in injection elsewhere, off-licence. Reasons for this may be due to the neck site being impractical and restricted by handling facilities, perhaps accounting for participants' off-licence vaccination location.

SC clostridial vaccines are also known to cause irritability and abscessation and may produce a local reaction that can persist for 10 weeks.[28] Therefore, straying away from the correct location could prove costly and possibly have detrimental welfare implications for the animal if an ISL occurs. It could be speculated that having ISLs has the potential for reduced vaccine efficacy if a vaccine deposit is eliminated by this abscessation. However, studies assessing this topic appear to be limited.

In an abattoir study, ISLs were present in 18% of adult sheep and 65% of lamb carcasses.[14] However, this is a small study of 20 sheep and, as far as the authors are aware, data do not go beyond this. Crosswell et al.[29] found a lower ISL prevalence of 4.1% ($n = 2853$) in the bovine industry, which would still be economically damaging but also suggested that, aside from vaccination, other factors contributed to ISL. Further research should, therefore, focus on the link between ISL and vaccination practice in sheep and accurately assess the economic cost associated with the location in which the vaccine is administered. This will establish the extent to which prime cuts are affected or to what extent the location injected is arbitrary. While this is economically damaging, it could also pose a question in relation to the sustainability of the industry, where the need for efficient food and minimal wastage is at the forefront of farming.[30] Wasting livestock through both ill-health (failure of vaccines) and trimming ISLs becomes environmentally costly with less useable protein for the consumer. This is particularly important given that the sheep industry has the potential to increase biodiversity, improve carbon capture and maintain ecosystems through sustainably managed grazing systems.[31] Therefore, this potential wastage becomes damaging to the industry.

There is a further problem associated with incorrect IM injection. The sciatic nerve runs through the hindlimb, the largest nerve in the body.[32] Vaccinating the wrong location in dairy cow cadavers strayed sufficiently close to the sciatic nerve to risk damage, which, in live animals, would cause pain, nerve

TABLE 11 Survey response to training versus correct location for the intradermal vaccine within coordinates

	Category	% (*n*)	Correct location for the intradermal vaccine within coordinates, % (*n*)	Significance
Did the individuals have training at some point (not defined)?	Yes	43.7 (117/268)	10 (21/219)	$p = 0.86$
	No	56.3 (151/268)	11 (24/219)	
Have the individuals been on a training course within the last 5 years?	Yes	30.0 (65/217)	4.6 (10/219)	$p = 0.84$
	No	70.0 (152/217)	16.4 (36/219)	

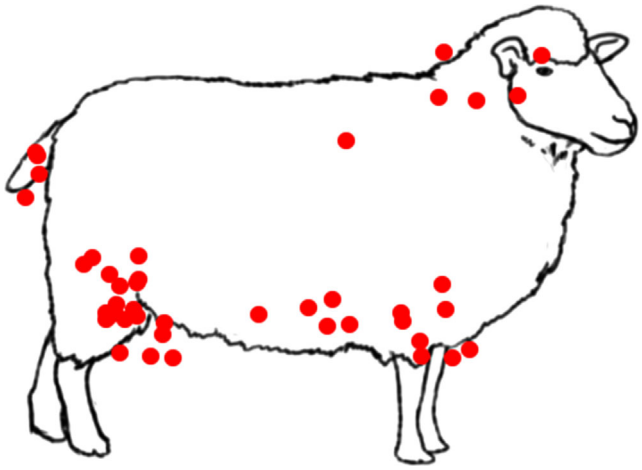


FIGURE 6 Diagram of the distribution of the participants on the sheep image when respondents were asked to mark on the diagram the location of where they would choose to inject the intradermal vaccine. This diagram shows the responses of only those who also stated they had used the only intradermal (orf) vaccine

function compromise and limb paralysis.[18] What is not clear is whether individuals would stray close to these structures in sheep, as there is no comparative study. In human patients with sciatic nerve damage to the gluteal region, the most common aetiology was IM injection, which presented as pain.[33,34] Similarities across species make this plausible in sheep. It is proposed that a cadaver study should be conducted to assess this risk and weigh up the need for farmers vaccinating in the neck.

There appears to be no evidence in veterinary research as to whether the correct location affects vaccine efficacy. This has only been speculated in the most recent study on intradermal vaccine location and does not generate these answers.[4] Research in human medicine suggests that vaccine efficacy is the same whether injected subcutaneously or intramuscularly.[35] It could be postulated that if the route does not affect vaccine efficacy, then perhaps location does not have an effect either. Further research is required to address this question in veterinary medicine.[36] Nonetheless, caution is required when considering location due to the other problems mentioned.[11]

A minority of participants indicated that they used the correct location for intradermal vaccination. There are known issues with this, for instance, in lambs, they are likely to reach (scratch) this region with their mouths, which may result in an active infection.[4] Furthermore, the incidence of mastitis and orf in ewes appear to be linked, and therefore, the correct vaccination technique is imperative.[37] It is, therefore, the responsibility of the veterinarian or SQP to communicate these risks and the correct location to the farmer to avoid misunderstanding. A study by Small et al.[4] found a similar distribution of locations when studying the use of the orf vaccine in an observational cross-sectional study of 586 respondents, validating the results in this study.

It must be noted that a minority answered that they used the orf vaccine. Of those who did use the vaccine, a small percentage identified the correct coordinates, suggesting that there is a misunderstanding among even those who use the vaccine. Participants who did not use this vaccine could have opted to not answer or comment 'I don't know', instead of answering. This suggests they thought they knew the correct location.

The rib area was identified as a location to give a SC vaccine by participants. This has been flagged as an alternative location on online platforms, and participants' behaviour might be influenced by this media. Equally, for IM injection, one manufacturer's instructional video showed injection into the rump. These locations are not the preferred region or indicated as preferred on its datasheet.[12,13] Nonetheless,

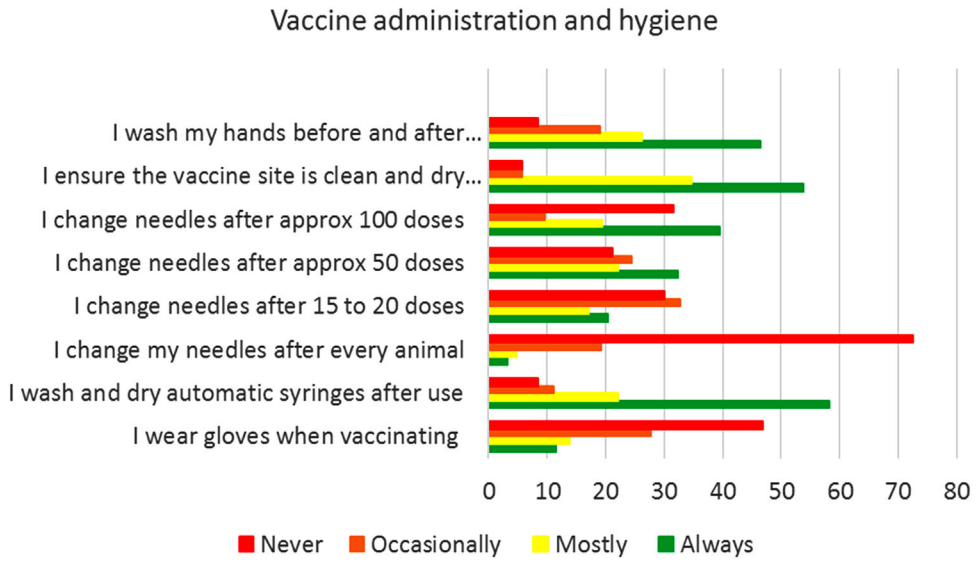


FIGURE 7 Distribution of responses to the question 'I wash my hands before and after vaccinating' ($n = 226$), 'I ensure the vaccine site is clean and dry' ($n = 225$), 'I change the vaccine site after every animal' ($n = 212$), 15–20 doses ($n = 217$), 50 doses ($n = 214$), 100 doses ($n = 190$), 'I wash and dry automatic syringes after use' ($n = 225$), and 'I wear gloves when vaccinating' ($n = 224$)

TABLE 12 Percentage of respondents to the questions 'When do you discard unused vaccines?' ($n = 235$), 'Where do you store your vaccines?' ($n = 221$), 'When did you last check the fridge temperature?' ($n = 218$), and 'What temperature do you store your vaccines at?' ($n = 220$)

	Category	% (*n*)	Training in the last 5 years, % (*n*)	Significance
When do you discard unused vaccines? ($n = 235$)	**I discard unused vaccine on the day of broaching**	**54.5 (128/235)**	**32.8 (42/128)**	$p = 0.139$
	I discard unused vaccine 48 hours after broaching	24.7 (58/235)	N/A	
	I discard unused vaccine after a week+	9.8 (23/235)		
	I keep unused vaccine to use next time	11.1 (26/235)		
Where do you store your vaccines? ($n = 221$)	**Specific fridge for veterinary medicines only**	**45.4 (100/221)**	**35 (35/100)**	$p = 0.237$
	Fridge for purposes other than for veterinary medicine	52.9 (117/221)	N/A	
	Non-refrigerated cabinet	1.4 (3/221)		
	Other	0.5 (1/221)		
When did you last check the fridge temperature? ($n = 218$)	**I have a temperature recorder**	**33.9 (74/218)**	23 (23/74)	$p = 0.545$
	I check it every day	**6.4 (14/218)**		
	I check it every week	11 (5) 5 (11/218)	N/A	
	I check it every month	7.8 (17/218)		
	I cannot remember	16.5 (36/218)		
	I do not check my fridge temperature	25.2 (55/218)		
What temperature do you store your vaccines at? ($n = 220$)	**At fridge temperature (2°C–8°C)**	**96.4 (212/220)**	**64 (64/212)**	$p = 0.441$
	Below fridge temperature (below 2°C)	0.5 (1/220)		
	At room temperature (17°C–23°C)	0.5 (1/220)		
	Other	2.7 (6/220)		

Note: For reference, the correct answer is highlighted in bold and this is considered in relation to whether the individual had answered whether they had training in the last 5 years.

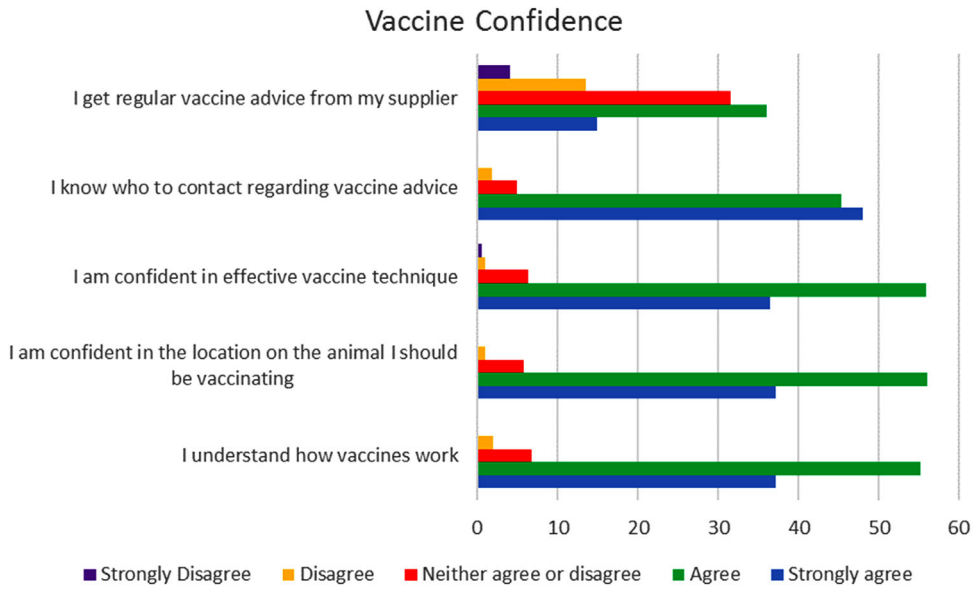


FIGURE 8 Distribution of responses to questions regarding vaccine confidence 'I get regular advice from my vaccine supplier' ($n = 222$), 'I know who to contact regarding vaccine advice' ($n = 223$), 'I am confident in effective vaccine technique' ($n = 222$), 'I am confident in the location of the animal I should be vaccinating' ($n = 223$), and 'I understand how vaccines work' ($n = 223$)

TABLE 13 Course names stated by those respondents who had been asked to state the course they had undertaken in the past 5 years ($n = 60$)

Categorised response	% (*n*)[a]
NPTC safe use of medicines	6.7 (4/60)
Responsible/safe use of medicines	11.7 (7/60)
Animal Medicines Training Regulatory Authority (AMTRA)	10 (6/60)
Merck Sharp & Dohme (MSD) training	1.7 (1/60)
ADHB	1.7 (1/60)
Mastering medicines	11.7 (7/60)
Courses by specific veterinary practices	21.7 (13/60)
Antimicrobial resistance courses	11.7 (7/60)
Milksure	1.7 (1/60)
Farm assurance use of medicines	6.7 (4/60)
University	6.7 (4/60)
Husbandry courses	3.3 (2/60)
Emergency vaccination refresher	1.7 (1/60)
Animal treatment course	1.7 (1/60)
National Sheep Association	1.7 (1/60)

[a]Only 60 of 218 respondents who answered whether they had been on a training course within the last 5 years stated the course.

TABLE 14 Training on vaccination technique: percentage of respondents to the questions 'Have you been on a training course within the last 5 years?' ($n = 217$), 'Are you aware of any training courses that you could attend to gain qualifications and understanding of safe use of medicines?' ($n = 218$), 'Would you consider going on training course online or in person to improve the safe use of vaccines?' ($n = 218$), and 'Are there any barriers to training?' ($n = 204$)

Training	Categories	% (*n*)
Have you been on a training course within the last 5 years? ($n = 217$)	Yes	30 (65/217)
	No	70 (152/217)
Are you aware of any training courses that you could attend to gain qualifications and understanding of the safe use of medicines? ($n = 218$)	Yes	26.1 (57/218)
	No	73.9 (161/218)
Would you consider going on training course online or in person to improve safe use of vaccines?	Online	27.2 (59/217)
	In person	13.4 (29/217)
	Both	43.3 (94/217)
	Would not consider	16.1 (35/217)
Are there any barriers to training?	Time	45.6 (93/204)
	Money	35.8 (73/204)
	Was not aware they existed	34.8 (71/204)
	Feel I already have the knowledge	40.7 (83/204)
	Do not feel they are relevant to me	4.4 (9/204)
	Location	26 (53/204)
	Do not feel there are enough people to fill the course	2.9 (6/204)
	Other	6.4 (13/204)

a problem thus arises between professional consensus on online platforms with differing information across these platforms compared to the exact wording of the datasheets. This gives farmers alternative areas for vaccinating; however, it does not provide a consistent message. While not all vaccines identify an explicit location, most either specifically do or at least recommend a site. Of more concern, if farmers fail to vaccinate according to datasheets that specify a location, they require a minimum of 28-day meat withhold due to using the product off-licence. Conversely, many datasheets do not specify a location, and currently, there are no industry-wide rules for this. However, it should be considered that the Agriculture and Horticulture Development Board (ADHB) advice identifies only two locations for IM and SC injection (Figure 1a).[11]

For the purpose of this paper, vaccines were combined by category (IM, SC, and intradermal). To determine compliance definitively to datasheets, it would

be necessary to study each vaccine individually. Thus, the term 'incorrect location' is considered too broad.

Use and storage

Using blunt needles or not changing needles between animals (when appropriate) is an important element of vaccination. Blunt needles are more likely to cause tissue trauma and damage, increasing the chance of ISLs. The majority of participants used a vaccine gun, with the remainder using a needle and syringe (13.6%). When using a needle and syringe, the datasheets recommendation is that a fresh needle is used each time the rubber cap is punctured. Most (72.6%) never changed their needle between animals. This is a problem: maximum bluntness occurs after four to five uses, but the needle begins to become blunt after one.[38] It is unknown how many of the respondents who never changed a needle used a vaccinating gun compared with a needle and syringe. Furthermore, the use of sterimatic devices was not explicitly mentioned in the survey, and therefore, it is not possible to establish whether these were used. Sterimatic devices are designed to be replaced every 100 animals and therefore respondents using these may have answered 'I change my needle every 100 doses'. It is noteworthy to mention that sterimatic devices are good practice for some vaccines, and thus, their use should be investigated further.

The majority indicated that they always stored their vaccines according to the datasheet, which is to store their vaccines at fridge temperature. However, what is concerning is that fridge temperatures are not checked regularly due to the variation in internal temperatures. Williams and Paixão[39] found that none of the 17 fridges on farms maintained a correct internal temperature during the study period (2°C–8°C). A further study found that 89% (n = 18) of fridge temperatures were outside the recommended range for storage.[40] Farmers may have up to £2000 worth of vaccines in a fridge at one time, and therefore this becomes a wasted investment.[41]

Vaccines should be disposed of according to their datasheets. All of the vaccines studied recommended disposal either on the day or within 8 hours of broaching. Only 54.5% dispose on the day of broaching, and 11.1% keep unused vaccines until the next time. Keeping after the disposal time is problematic. These are set based on real-time stability testing to determine whether the product still meets its requirements, and thus, it can be speculated that efficacy will be affected.[42] This raises several questions. Why are farmers doing this? Is there a gap in knowledge and understanding? Are they trying to prolong the use of the vaccine? Are farmers unaware that this may affect vaccine efficacy?

Improvements in vaccine use and storage can be achieved without significant economic investment but do require motivation and suitable education for farmers. Veterinarians and SQPs should advise minimal times of storage and promote the use of temperature loggers where vaccines have to be stored.

Vaccine advice and confidence

A minority purchased vaccines from their veterinarian (29.1%, 78/268). Conversely, 48.8% learned to vaccinate from their veterinarian, and only 10.1% (27/268) learned to vaccinate from their SQP. This is in contrast with other studies where 93% (n = 174) purchased from a veterinarian.[29] Nevertheless, this study is in agreement with others, in that the veterinarian has a significant role in advising about vaccination and has a role in training.[43] Not purchasing vaccines from their veterinarian could be a missed opportunity for communication about vaccination technique, especially when nearly half learned to vaccinate from a family, friend or neighbour. The consistency in training passed on from friends and family is unknown and may account for suboptimal vaccination techniques. The majority of farmers felt they were confident in vaccination technique; however, differing results in vaccination technique do not reflect this. Perhaps, from this, there is a clear need for interprofessional collaboration to bridge this knowledge gap. Professionals such as SQPs (now RAMAs) may also be pivotal in improving vaccine knowledge, given that in this study, a minority purchase their vaccines from a veterinarian, and this therefore should be emphasised when training. Furthermore, with increasing numbers of practices offering veterinary technician services, this may aid in compliance but also increase sales of prescription only medicine - veterinarian, pharmacist and SQP (POM-VPS) products, allowing veterinary professionals to become more involved.

Training in vaccination technique

There was a significant difference between those who gave the correct location for IM vaccination and those who had training or been on a course compared to those who had not. Investigating a larger sample size may demonstrate significance in other areas of vaccination techniques, therefore recognising a need to promote training courses for farmers. Alternatively, perhaps the reason there is no significant difference between the results for the location of SC and intradermal versus training could be that there is an assumption that those vaccinating know where they should be vaccinating; therefore, training may not focus on these vaccination types specifically. Furthermore, there may be a need for studies that analyse what is included in training and its standardisation. In addition, it should be highlighted that there are more SC vaccines than IM vaccines for sheep; therefore, perhaps these vaccines are more memorable.

Less than half had received training on vaccination administration, and only a third had been on a course (<5 years ago). Numerous courses were stated, indicating that training opportunities are likely adequate. However, the number of respondents unaware of any training courses they could attend, despite an overwhelming majority who would consider going on a training course, was staggering. This suggests that farmers are not unwilling to learn, but there is

a lack of awareness of courses available. There needs to be stronger advertising campaigns around what courses are available to farmers within the industry. To reach a wider population of farmers, both online and in-person courses should be offered and promoted, since the majority of farmers surveyed would consider both online and in-person courses. However, a proportion would only consider online and a smaller proportion only in person. Perhaps, since a large proportion learned to vaccinate from a friend, neighbour or family member, farmer-led training could be organised as part of open farm visits in collaboration with veterinarians. Alternatively, webinars may provide an alternative to those who prefer online and may be prerecorded to allow great accessibility to courses. However, it must be considered that although 27% said they would like online training, this may have been impacted by COVID-19. Farmers may have been more open to online training rather than in person due to the pandemic, and as such, a hybrid offering may address the larger majority going forward. Furthermore, since this survey was online, it reflects those likely to undertake online activity.

Moving forward, to drive best medicine practice, under Red Tractor assurance schemes, 'at least one person on-farm must have undertaken medicine training'. However, not all farms are Red Tractor accredited, and courses may be variable. Therefore, future courses should aim to include content on vaccination techniques. Other accreditation schemes may offer more stringent requirements; however, perhaps there is a need for standardisation across the industry. This may be helped by the animal health and welfare pathway reviews, which will allow farmers' own veterinarians to conduct fully funded visits every year. The question of who should be responsible for ensuring vaccination technique is optimal should be considered and is challenging to answer. Datasheets need to be explicit, which is the responsibility of the pharmaceutical company, since 71.1% (167/235) of respondents indicated they followed the datasheet when vaccinating. Furthermore, this is what veterinarians and SQPs will use, both of whom may be involved in training. Therefore, it requires a collaborative response from all industry representatives to encourage optimal practice.

Limitations

A total of 34,000 people are employed on sheep farms in the UK[44]; therefore, this study is representative of 1.1%. It is likely a biased population who is interested in the study. A large proportion had either further or higher education, which may have influenced the results. Participants included education as a form of training in vaccination techniques, which may have overestimated training. Other demographics were deemed representative. A larger sample size would be needed to be fully representative of the sheep industry and assess the true extent to which training is adequate.

There may have been recall bias, with farmers not necessarily answering the same as in the field. Asking to show on a 2D diagram where to inject 3D may have led to mis-indications. Therefore, further research should use cadavers to pinpoint more precisely where individuals would inject in relation to underlying anatomy, giving a more accurate assessment of iatrogenic damage through injection.

CONCLUSION

There are elements of suboptimal vaccination techniques within the industry. There should be a push within the industry to highlight these shortcomings in vaccination techniques and communicate them to the farming community. It is evident that, for the majority, it is not because of farmers' unwillingness to learn but perhaps a misunderstanding in vaccination technique or not knowing that there are training courses available. Therefore, it is the responsibility of the industry to communicate this and have a multidisciplinary approach between them to highlight areas where further training may be required.

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CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

AUTHOR CONTRIBUTIONS

Nicola Blackie and Lauren E. Hall were involved in conceptualisation, planning, study design, and setup. Lauren E. Hall, Nicola Blackie, and Beth Reilly were involved in survey testing and design. Analysis was carried out by Lauren E. Hall. The manuscript was prepared by Lauren E. Hall. All authors were involved in manuscript editing and read and approved the manuscript.

ETHICAL APPROVAL

The project was approved by the Royal Veterinary College (URN number: SR2020-0334).

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author.

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