WIN!
ME TIME
isn't all fun and games
How a dog enjoys their 'me time' can influence their level of parasite risk and therefore the level of protection they require.
Introducing Parassess®
A FREE online, easy-to-use parasite risk checker that helps owners to help you assess their dog's individual risk. Enables a timely, risk-based prescribing decision in your busy practice.
Scan the QR code for a chance to personalise your own 'ME TIME' with an Apple® bundle, and also win an iPad® for your practice*
Visit whatstherisk.co.uk or talk to your Boehringer Ingelheim Animal Health Territory Manager for more information.
NEW
WHAT'S THE RISK?
Parassess®
Check your dog's parasite risk.
*Terms and conditions apply, available at whatstherisk.co.uk. Alternatively please call 01344 746960 (UK) or 01 291 3985 (Ireland) or email vetenquiries@boehringer-ingelheim.com for more information and to access a copy.
An educational service from the makers of NexGard SPECTRA
Further information available in the SPC or from Boehringer Ingelheim Animal Health UK Ltd., RG12 8YS, UK. NexGard Spectra® is a registered trademark of Boehringer Ingelheim Animal Health France SCS, used under licence. Parassess® is a registered trademark of Boehringer Ingelheim Vetmedica GmbH, used under licence. ©2023 Boehringer Ingelheim Animal Health UK Ltd. All rights reserved. Date of preparation: May 2023. UI-CAN-0040-2023. Use Medicines Responsibly.
Apple® and iPad® are registered trademarks of Apple Inc., registered in the U.S. and other countries and regions.
Boehringer Ingelheim

Received: 25 April 2023 | Revised: 12 September 2023 | Accepted: 21 September 2023
DOI: 10.1002/vetr.3505

Vet Record

ORIGINAL RESEARCH

Assessing antibiotic usage data capture accuracy on dairy farms in England and Wales

Camilla Strang | **Pablo Alarcon** | **Jacqueline M. Cardwell** | **Lucy Brunton**

Veterinary Epidemiology, Economics and Public Health group, Department of Pathobiology and Population Sciences, Royal Veterinary College, Hatfield, UK

Correspondence
Lucy Brunton, Veterinary Epidemiology, Economics and Public Health group, Department of Pathobiology and Population Sciences, Royal Veterinary College, Hawkshead Lane, Hatfield, Hertfordshire, UK.
Email: lbrunton@rvc.ac.uk

Present address
Camilla Strang, Camilla Strang, Scott Dunn's Equine Clinic, Wokingham, UK

Funding information
Royal Veterinary College; Antibiotic Research UK, Grant/Award Number: ANTSRG 01/2018

Abstract

Background: Accurate farm-level data on antibiotic usage (ABU) are needed for the surveillance of antibiotic resistance. Therefore, this study aimed to determine the accuracy of ABU data capture by dairy farmers in South West England and Wales.

Methods: Through a cross-sectional survey of 48 dairy farmers, the accuracy of ABU recording was measured by farmers' assessment of the completeness and timeliness of ABU recording ('perceived accuracy') and the completeness and correctness of on-farm ABU records ('actual accuracy'). Completeness and correctness were compared for paper and software recording methods.

Results: Perceived accuracy was higher than actual accuracy. Antibiotic names, withdrawal periods and dates that products were fit for human consumption were often incomplete or incorrect. More inaccuracies were seen with paper than software. In some software platforms, the date that milk would be fit for human consumption was frequently rounded down by half a day, increasing the risk of residue failures.

Limitation: The small number of on-farm records assessed limits the generalisability of the results.

Conclusions: Electronic recording of ABU should be encouraged. However, functionality needs improvement, alongside consultation with dairy farmers to increase awareness of inaccuracies.

INTRODUCTION

Collection of data on antibiotic usage (ABU) in the dairy industry allows for the monitoring of patterns and trends in consumption and antibiotic resistance (ABR), facilitates risk assessment of ABR through targeted surveillance, allows evaluation of control measures and facilitates integrated analysis of the occurrence of shared antibiotic-resistant bacteria in dairy animals and the human population.[1] In the UK, the Veterinary Medicines Directorate (VMD) currently relies on pharmaceutical sales and a sub-section of veterinary sales data to provide information on ABU in the dairy industry. However, this is limited to providing an aggregated amount of antibiotics used. While this can be used to monitor patterns and trends in consumption, it does not allow for more in-depth monitoring of ABR or for more targeted surveillance to understand the impact of ABU in the dairy industry on the development of ABR within and between dairy and human populations. The limitations of current data collection systems have been recognised through recent Veterinary Antibiotic Resistance and Sales Surveillance (VARSS) reports[2–7] and the European Medicines Agency.[1] To address this issue across the European Union (EU), EU legislation requires the collection of actual ABU data per animal species through semi-automated harmonised systems by 2023.[1]

On-farm antibiotic treatment records should provide the most detailed data on ABU. Under legislation[8] and assurance scheme requirements,[9] dairy farmers are required to maintain purchase and treatment administration records for 5 years, but in no standardised format. Records are expected to be complete and made available to a farm assessor at a planned annual or 18-month farm audit, which is required for market access. However, the most common method

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.
© 2023 The Authors. *Veterinary Record* published by John Wiley & Sons Ltd on behalf of British Veterinary Association.

of assessing the completeness of these records is visual inspection, which does not always cover the time period between audits. Therefore, inconsistent or missing data entries for required variables may not be noticed.

To overcome this and to meet EU legislation, there is a need for the development of a centralised system to collate and assess such data. However, to achieve successful implementation, further understanding of how farmers are recording their on-farm ABU, the successes and limitations of current recording systems and how effective those systems are at facilitating the capture of ABU are required. This will help identify potential biases in existing data collection methods and provide guidance for the development of an optimised system. The objectives of this study were to measure and compare the perceived accuracy and actual accuracy of ABU recordings by dairy farmers in South West England and Wales and to determine whether actual accuracy is associated with the type of data capture system used.

MATERIALS AND METHODS

Study design and sampling

A cross-sectional study was conducted using in-person interviews to complete a questionnaire and retrospective collection of on-farm medicine records. The study population was dairy farms in South West England and Wales. These two regions account for 42% (n = 3932) of dairy herds in England and Wales, as of October 2018 (based on county parish holding numbers).[10] The South West England region was defined as the counties of Cornwall, Devon, Somerset and Dorset. All dairy farmers with a registered cattle holding and a total herd size of greater than 50 were eligible to participate.

The sample size required to detect a significant difference between two proportions, that is, a difference in ABU recording accuracy between electronic (p1) or paper-based (p2) data capture systems, was calculated using an assumed accuracy of 80% in p1 and 50% in p2, a confidence level of 95%, a desired power of 80% and a ratio of sample sizes (p2/p1) of 2. This ratio was used since it was expected that more respondents would be using paper-based recording than electronic recording. A sample size of 99 was required, with 33 in p1 and 66 in p2.

It was not possible to establish a sampling frame for probability-based sampling due to not having access to existing farmer contact lists. Therefore, access to dairy farmers within these regions used two non-probability sampling methods—convenience and snowball, as outlined below. The aim was to capture a diversity of farmers to reflect the different types of dairy farms present in England and Wales, and therefore achieve findings that could best translate to the industry. Diversity sampling involved targeting a range of herd sizes and management types, such as calving patterns and average annual milk yield. The approaches to recruitment were as follows:

1. Delivery of a 5-minute study outline presentation at five of the annual Arla Foods 2018 Vet CPD meetings on 'Treat, sleep, test, repeat. Testing for medicine residues—what we do, what we find and the importance of antibiotic recording'. A reminder email was sent by Arla Foods to veterinary attendees upon meeting completion to prompt responses from interested persons.
2. Direct and indirect contact with RCVS-accredited farm animal practices in Cornwall (n = 10) and Dorset (n = 3).
3. Presentation of the study outline to partners from three RCVS-accredited farm animal practices linked to the Royal Veterinary College (RVC) on 27 February 2019.
4. Presence on the National Milk Records stand at the 2019 Royal Welsh Agricultural Show to outline the study and obtain contact details of consenting Wales-based dairy farmers.
5. Use of familial networks to contact dairy farmers.

Approaches 1–3 relied on veterinary practice involvement, with veterinary surgeons either providing access to their contact list (further detail provided in results: response rate) or speaking to farmers on routine visits in return for the researcher collating the annual amount of ABU on farms visited as per assurance scheme requirements. Approaches 4 and 5 used direct and indirect contact with farmers through mutual contacts.

Data collection

Review of data capture systems

Farm management software companies facilitating ABU data capture or recording for the dairy industry were identified through various sources. These included gov.uk listing of cattle tracing system software, a Google search using the search term 'dairy farm record keeping software UK' and discussions through agricultural networks. Companies were contacted via telephone and asked to provide information on the number, geographical distribution and demographics of end users along with medicine record-keeping functionality. For those with whom contact was not possible, publicly available information was obtained from their websites.

Questionnaire development and distribution

Questions were divided into five sections encompassing the dairy enterprise, data collection and recording on ABU, ABU practices, herd health and participant demographics. To identify antibiotics used on farms, the VMD-licensed product spreadsheet and

20427670, 0, Downloaded from https://bvajournals.onlinelibrary.wiley.com/doi/10.1002/vetr.3505 by Test, Wiley Online Library on [11/10/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

the National Office of Animal Health (NOAH) compendium were used to create a list of available products under three routes of administration: injectable, intramammary and other (oral and topical). Products were cross-checked against online pharmacies to identify those used regularly and those that may have gone out of production. Prior to distribution, the questionnaire was reviewed by three veterinarians with knowledge of the dairy sector and two dairy farmers and was provided to them in paper format. Veterinary feedback was collected from one farm animal clinician, one industry veterinarian and one government veterinarian, each with a working focus on antimicrobial resistance. Questionnaire length was identified as a potential issue, but it was concluded that the use of mostly closed-format questions would reduce completion time. Farmer feedback involved 'think-aloud' analysis, whereby participants could verbalise their thoughts to the task facilitator. Two dairy farms in England with different management characteristics were represented. Three questions were removed and four amended, either because they were not applicable to all dairy enterprises or because the information requested was seen as having a limited contribution to herd health and management protocols. In order to maximise the response rate to questions on herd health, where consultation of farm records could be required, respondents could provide estimates of disease incidence as an alternative to actual values.

The questionnaire was piloted online with a final revised and shortened version administered via in-person interviews due to a poor online response rate. The finalised questionnaire (available in Supporting Information) comprised 48 questions, of which three were open ended. Two open-ended questions were used to verify answers to two closed questions relating to knowledge of highest priority critically important antibiotics (HP-CIAs) and use of selective dry cow therapy, and one was used to expand on the response to a closed question on data sharing of on-farm ABU records. In-person interviews occurred between April and October 2019, and a £10 Amazon voucher or cash alternative was provided to incentivise participation.

Data collection and handling

To assess the accuracy of ABU recording, the previous 12 months of the farm medicine book were copied by the researcher at the time of the visit, with participant permission. Copies of electronic records were in PDF or Microsoft Excel spreadsheet format. For paper records, a photo of each page was taken. Copies were uploaded to RVC central drives for security and removed from intermediary technology.

Each respondent was given a unique identification (ID). Data from completed questionnaires were entered into a Microsoft Access relational database using restricted data entry forms to minimise errors. Data from medicine records were entered into a preformed structured tabular format in Microsoft Excel designed to capture data completeness and correctness. Paper medicine records were entered manually, while data in Excel spreadsheets were cleaned and imported. For structured PDF medicine records, Microsoft Power Query was used to import data. For each PDF record, a random selection of entered data was reviewed against the original to check for errors. Missing values or erroneous entries across all medicine records were identified through the following data consistency queries:

- Milk and meat withdrawal periods were compared to the antibiotic-specific datasheet withdrawal periods, and any withdrawal periods deviating from the datasheet were reviewed for correct data entry.
- For date treatment finished and dates milk and meat were fit for human consumption, the difference between these dates was expected to equal the datasheet withdrawal period. Where the difference between these dates did not conform to the expected value, the data entry was checked for accuracy against the original records.
- Missing values for all fields were reviewed to ensure that this was not a data entry error.
- All significant outliers were manually checked against the original records.

Erroneous entries were amended by the researcher to the value recorded in the medicine book. Additional commentary specific to each set of records and recording method was entered into a separate Excel spreadsheet as free text to provide potential explanatory reasons for a participant's erroneous entry or missing data.

Data analysis

Descriptive analysis of questionnaire responses

Data analysis was performed in R software (version 3.6.2; R Core Team, 2019). Herd size, number of cows in milk and number of employees were used as proxies to estimate the size of the enterprise. Calving pattern, primary breed type, organic status, type of contract, mixed production and use of selective dry cow therapy were used to provide an overview of the management system. Categorical variables relating to dairy enterprise, data collection and recording on ABU, ABU practices, herd health and participant demographics were summarised by number and percentage. Data were checked for normality by both visual inspection and the Shapiro–Wilk test. Continuous variables were described using mean and 95% confidence intervals (CIs) for the mean or median and range, as appropriate depending on distribution. The modified Cox method was used to calculate 95% CI if the distribution was non-normal.

20427670, 0, Downloaded from https://bvajournals.onlinelibrary.wiley.com/doi/10.1002/vetr.3505 by Test, Wiley Online Library on [11/10/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Development of an accuracy score based on questionnaire responses: perceived accuracy

Questionnaire responses provided two measures of participants' perceptions of recording accuracy: timeliness and completeness. Timeliness refers to the prompt entry of required data on antibiotic treatments into a recording system (questionnaire Section 2, questions 3 and 4), and completeness refers to the presence of all required data under legislative and assurance scheme requirements plus the date meat becomes fit for human consumption (questionnaire Section 2, questions 9–11; Table 3). A simple scoring system for timeliness and completeness was applied (Figure S1). Each response was weighted equally, with the overall score expressed out of 10 for ease of interpretation and comparison.

The normality of the data distribution was assessed by visual inspection and the Shapiro–Wilk test. The median, interquartile range (IQR) and range were used to describe perceived recording accuracy, timeliness and completeness, and the Wilcoxon rank sum test was used to test for an association between these outcomes and the recording method.

Development of an accuracy score based on on-farm records: actual accuracy

Medicine records were assessed for the completeness and correctness of antibiotic entries. Correctness refers to the percentage of recorded observations that were correct. Further details on the development of the actual accuracy score are provided in the Supporting Information.

The correctness and completeness scores were summed and expressed out of a maximum score of 10 (Figure S2). The normality of the data distribution was assessed by visual inspection and the Shapiro–Wilk test. The median and IQR were used to describe actual recording accuracy, and the mean and standard deviation were used for completeness and correctness. The Wilcoxon rank sum test was used to test for an association between the recording method and actual recording accuracy.

Comparative analysis of perceived versus actual accuracy

To explore the potential impact of information bias on participants' self-reporting of their perception of recording accuracy, the Wilcoxon rank sum test was used to test for an association between perceived and actual accuracy.

Assessment of data entry completeness and correctness for paper and software recording methods

Generalised estimating equations (GEEs) with a logit link function were used to test for an association between recording method (software or paper) and data entry completion and correctness at the treatment level while adjusting for farm-level clustering using an exchangeable correlation structure. For completeness, this comprised each recording variable identified in Table 3, aside from the name and quantity of antibiotic and animal ID. For correctness, this comprised antibiotic name and dates milk and meat are fit for human consumption. Odds ratios (ORs) and the respective 95% CIs and *p*-values were calculated for each of the recorded variables.

RESULTS

Review of data capture systems

Of the seven farm management software companies contacted, four were able to provide relevant information about the use and features of their tools (Table 1). From this information, it was estimated that around 40% of dairy farmers in Great Britain have the option of using software to record antibiotic treatments. They had a widespread distribution of users of varying ages throughout Great Britain. Six of the seven software platforms reviewed had a mobile phone app function to facilitate recording of ABU at the time of treatment, although uptake of this is not known. Of these six, three enabled the scanning of a QR code on medicine packaging, resulting in automated entry of antibiotic name, batch number and product expiry date. Four provided a standardised medicine list to aid precision with antibiotic name entry. For the length of the milk withdrawal period, two software platforms facilitated entry of full days only, and not hours, and encouraged users (via an automated prompt message) to round up where the withdrawal period was not an exact number of full days.

Response rate

Farmer recruitment through veterinary involvement had a poor response, despite veterinary interest in the topic. However, one veterinary practice linked to the RVC permitted access to their client contact list when on site. This practice placed a notice in their quarterly client newsletter giving a brief summary of the study and stating that an RVC researcher may be in contact in due course to ask about participation. This provided the opportunity for farmers to opt out if they did not want their contact details to be shared. The contact list was only accessible to the lead author while at the practice offices, and farmers were only contacted from the practice phones. If farmers agreed to participate, their contact details were temporarily held by the lead author until the farm visit had been completed. Of the 115 farmers contacted through simple random sampling of the client list, 37 (33%) agreed to participate. Through convenience and snowball sampling, 75 farmers were identified, with 66 (88%) agreeing to

20427670, 0, Downloaded from https://bvajournals.onlinelibrary.wiley.com/doi/10.1002/vetr.3505 by Test, Wiley Online Library on [11/10/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE 1 Overview of farm management software facilitating the recording of antibiotic usage

Software	Users (*n*)	Smartphone app	QR code	Standardised medicine list
Uniform	1600	✓	✓	✓
Interherd	360	X	X	✓
Herdwatch	1000	✓	✓	✓
Sum-It total dairy	600	✓	X	X
CIS	–	✓	–	–
Orchid farm wizard	–	✓	✓	–
Stock move express	–	✓	X	✓

Note: '–' indicates no information available.

participate. In total, 103 farmers completed the questionnaire via structured interviews, and 48 medicine records were available for analysis.

Study population

Participating farms were distributed across South West England (Cornwall, Devon, Dorset and Somerset), Hertfordshire and Wales (Table S1). Farm-level variables relating to the size of the enterprise and management factors are presented in Table S2 (questionnaire Section 1). The median number of cows in milk (animals over 2 years of age) was 180.

Most participants were male and occupying senior positions in farm management, with farm owners, managers and tenancy holders making up 92.2% of the study population. Four responses were from herdspersons and four from family members. Six participants were under 30 years old and 13 were 60 years or older. Many participants had more than 30 years of dairy farming experience (Table S1; questionnaire Section 5).

The most popular method for the official recording of medicine use (56%; $n = 58$) was electronic, with access to information technology (IT) and the internet being key facilitators (Table 2; questionnaire Section 2, questions 5 and 6). However, paper records, predominantly in the form of a daily diary, were used by all participants as an initial record. Eleven different software platforms were used, with Uniform being the most popular (Table 2; questionnaire Section 2, question 7).

TABLE 2 Variables collected to understand the on-farm recording process

Variable	Response	Number of farms (%)
Medicine book format	Paper	45 (44)
	Software	58 (56)
Type of software	Uniform	28 (48)
	CIS	3 (5)
	Excel	5 (9)
	Orchid systems	3 (5)
	Farm metrics	3 (5)
	Herdwatch	4 (7)
	Interherd	6 (10)
	Sum-It	3 (5)
	Kingswood	1 (2)
	Lely Time 4 Cows	1 (2)
	Dairy Comp 305	1 (2)
Initial treatment communication[a]	Text message/WhatsApp	96 (93)
	Verbally	86 (84)
	Noticeboard/calendar	55 (53)
	Daily diary	103 (100)
	N/A—do the treatment and recording	9 (9)
	Other	12 (12)
Access to IT and internet	Yes, both	76 (74)
	Computer/tablet but slow or no internet	23 (22)
	No computer or tablet	4 (4)

Abbreviation: IT, information technology.
[a]More than one option could be selected.

Accuracy

Perceived accuracy

Perceived accuracy was measured using the questionnaire responses ($n = 103$). The overall median (IQR) perceived accuracy score was 9.6 out of 10 (±0.6). The median score was 9.5 (±0.5) for paper recordings and 9.7 (±0.5) for electronic recordings ($p = 0.08$).

Timeliness: Most participants (75%; $n = 77$) initially recorded antibiotic administration in a daily diary at the time of treatment, with 24% ($n = 25$) recording this later that day (questionnaire Section 2, question 3). Official medicine book entries were completed daily by 35% ($n = 36$) of the participants, weekly by 42% ($n = 43$), and monthly or quarterly by 20% ($n = 21$) (questionnaire Section 2, question 4). Two participants (1.9%), who both used paper methods, updated their medicine book prior to an annual inspection. The median (IQR) timeliness score was 7.0 out of 8 (±2.0), and there was minimal difference (0.25) between paper and electronic recording ($p = 0.94$).

20427670, 0, Downloaded from https://bvajournals.onlinelibrary.wiley.com/doi/10.1002/vetr.3505 by Test, Wiley Online Library on [11/10/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE 3 Completeness of recording of compulsory variables at the farm level for assessing actual recording accuracy

Recording variables	Completeness (%)	SD[a]	Included in analysis of record completeness	Required by legislation	Required by FAS
Name of antibiotic	99.9	0.09		✓	✓
Quantity administered	99.9	0.01		✓	✓
Batch or bottle number linked back to purchase records	94.7	0.19	✓	✓	✓
Animal identification	99.9	0.06		✓	✓
Date of administration	97.1	0.20	✓		✓
Date treatment finished	98.6	0.14	✓		✓
Length of withdrawal period for milk	70.3	0.41	✓	✓	✓
Length of withdrawal period for meat	68.9	0.41	✓	✓	✓
Date when milk becomes fit for human consumption	73.3	0.30	✓		✓
Date when meat becomes fit for human consumption	69.4	0.35	✓		
Name of person administering antibiotic	67.4	0.41	✓		✓
Reason for treatment	88.3	0.30	✓		✓

Abbreviations:FAS, farm assurance scheme; SD, standard deviation.
[a]SD: lower bound of 0, upper bound of 1.

Completeness: A small majority (54%; n = 56) of participants reported recording all on-farm antibiotic treatments, while 39% (n = 40) admitted that some treatments slipped through the net. Four participants (4%) only recorded two-thirds of antibiotic treatments and three participants (3%) admitted struggling to keep records up to date(questionnaire Section 2, question 10). Of the compulsory data entry fields, all participants reported completing the name of the antibiotic and animal ID every time. Antibiotic quantity and treatment start and finish dates were reported to be always completed by 97% (n = 100), and the batch number, withdrawal period length and when milk and meat are fit for human consumption were reported to be always completed by 94% (n = 97) of participants. Person(s) administering treatment and treatment reason varied most, with only 79% (n = 81) and 88% (n = 91), respectively, reporting they completed these fields every time. Antibiotic treatment outcome, a non-compulsory variable, was recorded by 19% (n = 20), of whom 50% (n = 10) did so every time (questionnaire Section 2, question 9). The median (IQR) completeness score was 51.0 out of 52 (±3.0), with no difference between paper and software users.

Actual accuracy

Actual accuracy was measured using the medicine records (n = 48). The overall median (IQR) actual accuracy score was 7.8 out of 10 (±1.5). The median scores for paper and software were 7.5 (±1.5) and 8.2 (±1.5) out of 10, respectively (p = 0.05).

Of the compulsory recording variables, animal ID, name of antibiotic and quantity recorded showed minimal variation at the farm level, so they were excluded from the analysis of record completeness (Table 3). The mean completeness scores for paper and electronic records were 32.7 (±8.0) and 37.2 (±5.4) out of 45, respectively (p = 0.07).

Of the 10,764 treatment-level data entries, 63% (n = 6819) were electronic and 37% (n = 3945) were paper based. GEE modelling (Table 4) indicated that the odds of completion of milk and meat withdrawal periods for each treatment entry were approximately four times higher for electronic versus paper recording, while the odds of completion of the date when milk and meat would be fit for human consumption were around three times higher. The date of administration of an antibiotic was also significantly more likely to be recorded electronically than in paper records, but this should be interpreted cautiously because of quasi-separation in the data.

The overall mean correctness scores for paper and electronic recordings were 8.5 (±2.5) and 9.8 (±2.1) out of 15, respectively (p = 0.07). At least one antibiotic name had been entered incorrectly on 69% (n = 33) of farms (Figure 1), with those using software almost twice as likely to enter the correct antibiotic name (OR 1.96; 95% CI 1.00–3.86; p = 0.05). Antibiotic name inaccuracies were due to participant-specific shorthand (Table S3).

Of the data entries for when milk was fit for human consumption, 12.1% (n = 1229) were early, and on average by 4.9 days (Figure 2). In comparison, 6.2% (n = 663) of data entries for when meat would have been fit for human consumption were early, on average by 25.6 days (Figure 3). For meat dates, the proportion of errors did not differ significantly between electronic and paper records (p = 0.56). The odds of the date for milk being entered correctly were 2.19 times higher for electronic than for paper records (95% CI 1.14–4.22;

20427670, 0, Downloaded from https://bvajournals.onlinelibrary.wiley.com/doi/10.1002/vetr.3505 by Test, Wiley Online Library on [11/10/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE 4 Number and percentage of farm records that captured each variable, and generalised estimating equations (GEE) parameter estimates for the association between recording method and completeness of recording variable, adjusted for farm, with paper recording as the reference value

Recording variable	Recording method: Paper *N*	Paper %	Software *N*	Software %	Parameter estimates Odds ratio (95% CI)	*p*-Value[a]
Batch number						
Recorded	3535	90	6674	98	3.9 (0.7–21.6)	0.130
Not recorded	410	10	145	2		
Date meat fit for human consumption						
Recorded	1872	48	5721	84	3.1 (1.1–9.0)	**0.036**
Not recorded	2073	52	1098	16		
Date milk fit for human consumption						
Recorded	2020	51	5919	87	3.4 (1.0–10.9)	**0.044**
Not recorded	1925	49	900	13		
Date of administration[b]						
Recorded	3653	93	6818	100	66.6 (6.3–704.8)	**<0.001**
Not recorded	292	7	1	0		
Date treatment finished[b]						
Recorded	3766	96	6804	100	3.8 (0.4–34.8)	0.240
Not recorded	179	4	15	0		
Meat withdrawal period						
Recorded	1798	46	5721	84	4.1 (1.3–12.6)	**0.015**
Not recorded	2147	54	1098	16		
Milk withdrawal period						
Recorded	1808	46	5864	86	4.3 (1.3–14.2)	**0.015**
Not recorded	2137	54	955	14		
Person administering treatment						
Recorded	1745	44	5266	77	2.3 (0.7–7.3)	0.150
Not recorded	2200	56	1553	23		
Treatment reason						
Recorded	3554	90	5974	88	1.1 (0.3–3.5)	0.914
Not recorded	391	10	845	12		

[a]Significant *p*-values (<0.05) highlighted in bold.
[b]Quasi-separation therefore caution required with interpretation of estimates.

$p = 0.02$). For milk withdrawal periods that did not equate to a full day, such as 4.5 days for one common intramammary preparation, more data entry errors were observed for both recording methods. The date that milk would be fit for human consumption was frequently rounded down by half a day, particularly in electronic records.

Perceived versus actual accuracy

The perceived and actual accuracy scores were substantially discrepant (Figure 4). Perceived accuracy was tightly clustered towards the maximum score, indicating that participants viewed their ABU recording as highly accurate. On-farm records showed recording to be less accurate than participants perceived ($p < 0.001$), irrespective of the recording method.

DISCUSSION

This is the first study in Great Britain to assess the accuracy of recording antibiotic treatments on dairy farms and make a direct comparison between electronic and paper records. Key findings are that farmers' perceptions of recording accuracy did not match reality, electronic records captured ABU data more accurately than paper records, and there is a class of errors unique to electronic records resulting from the interaction of farmers with their software platform.

Variables with a high level of accuracy across both recording methods were animal ID and name and quantity of antibiotic. Similar results have been reported on Swiss dairy farms, although animal ID was found to be less well recorded in paper records.[11] The start and finish dates of treatment, treatment reason and the person administering treatment were also

20427670, 0, Downloaded from https://bvajournals.onlinelibrary.wiley.com/doi/10.1002/vetr.3505 by Test, Wiley Online Library on [11/10/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

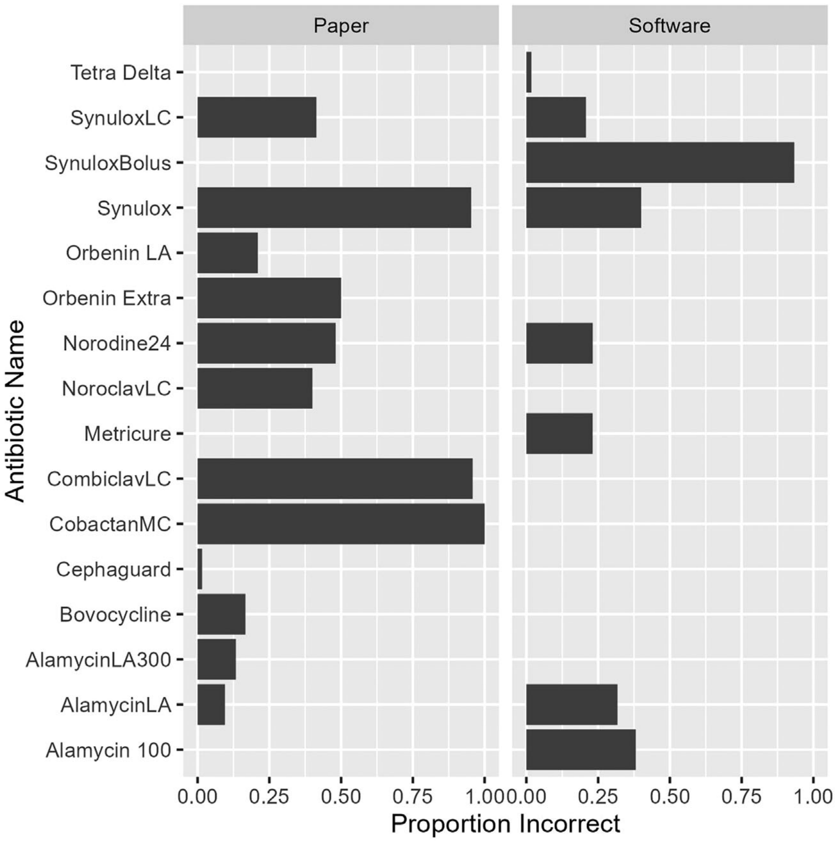

FIGURE 1 Comparison showing the higher proportion and range of antibiotic name inaccuracies using paper records (87% overall; $n = 20$) compared with electronic records (52% overall; $n = 13$) (antibiotics with 100% accuracy for both recording methods excluded)

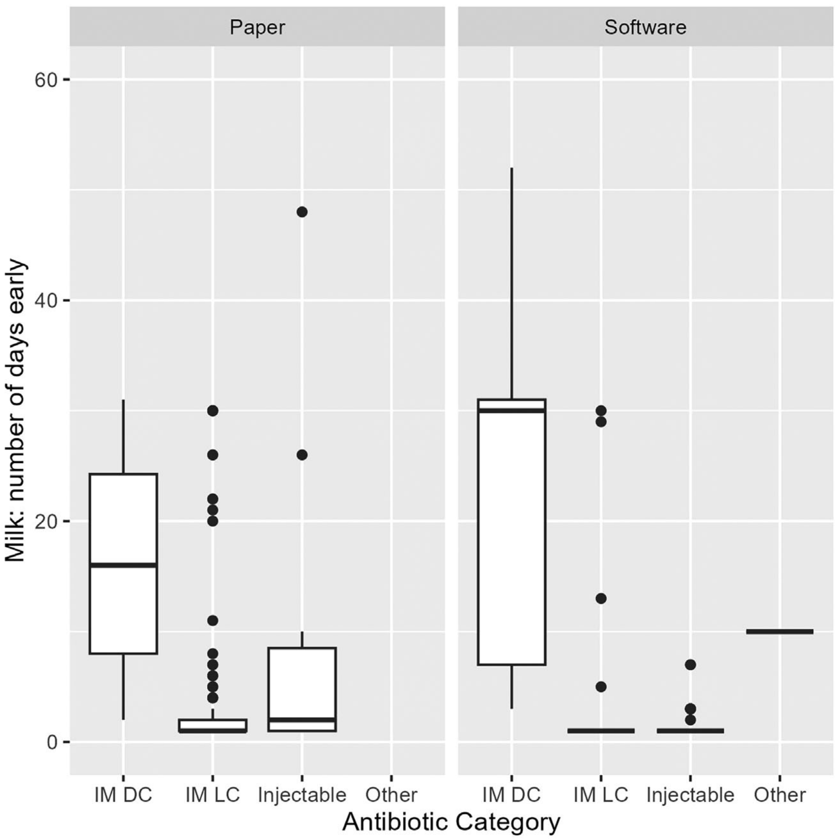

FIGURE 2 Comparison of data entry errors between paper and electronic records for the underestimation of milk withdrawal periods for each drug category. IM DC: intramammary dry cow; IM LC: intramammary lactating cow; other: topical or uterine

well recorded. Such information is likely to be easy to complete, and the presence of a daily diary, which all farmers reported using as the first step for recording ABU, would have aided recall.[12] Inaccuracies in the recording of antibiotic names emphasised the importance of standardised medicine lists in software programs to remove any uncertainty over the product used. González et al.[11] reported that farmers' lack of awareness that drugs exist in multiple formulations could result in them not specifying which had been

20427670, 0, Downloaded from https://bvajournals.onlinelibrary.wiley.com/doi/10.1002/vetr.3505 by Test, Wiley Online Library on [11/10/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

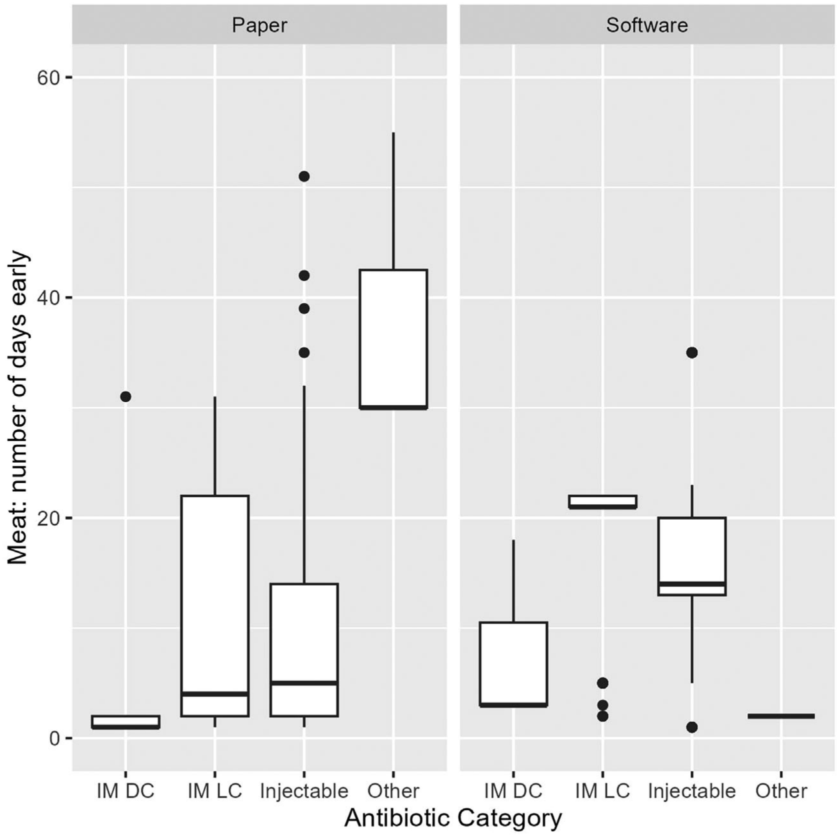

FIGURE 3 Comparison of data entry errors between paper and electronic records for the underestimation of meat withdrawal periods for each drug category. IM DC: intramammary dry cow; IM LC: intramammary lactating cow; other: topical or uterine

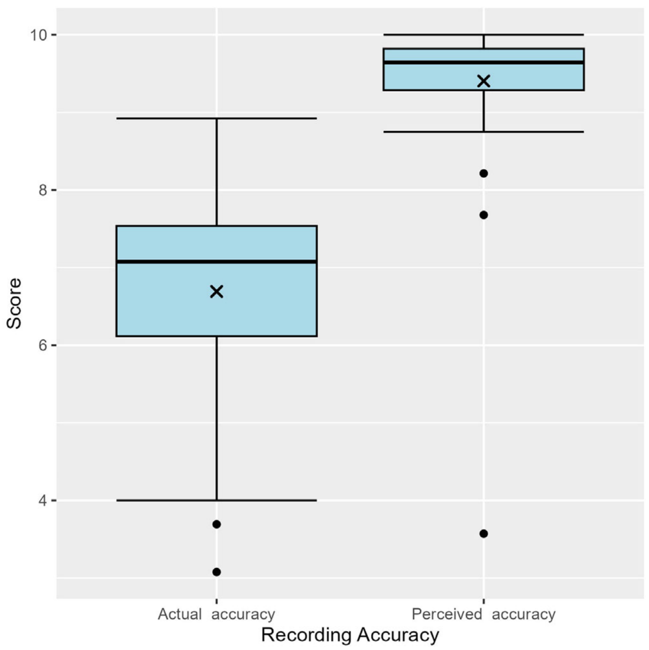

FIGURE 4 Box plots outlining the median, first and third percentile, range and mean (x) to show the difference between actual accuracy versus perceived accuracy scores on recording antibiotic usage on farms

used. Inaccuracies in the recording of antibiotic names could lead to incorrect calculation of withdrawal periods and affect collation of data at the product level for subsequent analysis.

There was a high degree of variation in the completeness and correctness of the recording of withdrawal periods for milk and meat and the resultant dates that milk and meat are fit for human consumption. There were more data entry errors for the date milk is fit for human consumption with paper records compared with electronic records. This raises concerns about food safety and the risk of antibiotic residues entering the food chain, emphasising the importance of the stringent control measures already in place in the supply chain. Farmers are primarily responsible for reducing residue failures by adhering to the medicine withdrawal periods. This is complemented by testing for residues in the supply chain.[13,14]

Electronic recording has been shown to allow better traceability of treated dairy cattle[11] and improve the accuracy of human medication documentation.[15–17] Similarly, in this study, the use of electronic records was associated with higher recording accuracy. Electronic records were more complete for all variables, although this was only statistically significant for antibiotic withdrawal periods and dates that produce are fit for human consumption, possibly due to the low study power. Electronic recording supports structured and systematic data entry and validation, and depending on the software platform, a range of variables can be auto-populated via a QR code. With paper recording, even when using a structured tabular format, there is room for error at each step of data entry, with no restrictions on what can be written for each variable and no internal cross-validation.

As the completeness of antibiotic names was very high for both recording methods, it was expected that milk and meat withdrawal periods and dates that meat and milk would be safe for human consumption would be similarly complete in electronic records because of pre-loaded withdrawal periods linked to

20427670, 0, Downloaded from https://bvajournals.onlinelibrary.wiley.com/doi/10.1002/vetr.3505 by Test, Wiley Online Library on [11/10/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

the antibiotic name. In fact, only one of the seven evaluated software packages facilitated the automatic entry of withdrawal periods, despite this information being available from pharmaceutical suppliers, the NOAH compendium and the VMD database. The use of automatically updated withdrawal periods that also encompass animals on combined treatments could increase the efficiency and accuracy of on-farm electronic data capture.

The number of inaccuracies in recording the date that meat and milk would be safe for human consumption, giving rise to the risk of antibiotic residue failures, was concerning. Errors were particularly high when the milk withdrawal period was given in hours, not complete days. While software packages will automatically calculate dates safe for human consumption when the withdrawal period has been entered, they are set up to work in full days, and the time that the antibiotic was entered is assumed to be the first minute of the date entered. Therefore, the calculated date safe for human consumption may be too early, despite the correct information being entered. Software could be improved by defaulting to the assumption that antibiotics are given at the end of the day. Alternatively, for two existing platforms, withdrawal period entry could be restricted to full days, with a prompt message to round up to the next day. In practice, farmers may have other control methods to prevent incorrect withdrawal periods, such as visual markers on animals or the daily diary. Nevertheless, as software companies develop more complete and coherent packages governing farm operations, it is possible that this risk increases.

The clustering of perceived accuracy towards the maximum score provided valuable information. If a farmer perceives ABU recording to be highly accurate, they may not check records sufficiently frequently. This could be a particular problem when they are not the sole person recording treatments, as observed on mixed-species farms.[18] This might also suggest a lack of concern about the value of accurate ABU recording. Since recording is required under both legislation and assurance schemes, social desirability bias might have influenced responses, resulting in overestimation of accuracy,[12,19,20] particularly because data were not gathered anonymously.[12,21,22] This was addressed where possible through obtaining retrospective records.

The total number of on-farm treatment records assessed was low relative to the number of dairy farms in Great Britain, and sample size requirements were not met. The sample size calculation was also based on an assumption of random sampling and so is likely to have been an underestimation of the sample required, which will have reduced the sensitivity of the study and increased the probability of a type 2 error. ABU was perceived as a sensitive topic by the veterinarians and farmers contacted, and veterinary practices reported that participation in research was a low priority due to high workload, as found in medical general practice.[23] Commonly reported stressors such as high workload and the perception of treatment of farmers in society and popular media are likely to have been risk factors for a poor response rate, especially on a sensitive topic.[24] This, alongside the lack of anonymity, may have impacted willingness to share treatment records, especially if not up to date. Direct contact provided an opportunity for discussion, questions about the research and assurances of confidentiality, which have been reported elsewhere as significantly associated with increased response rates.[25] The focus on South West England and Wales as well as the use of non-probability-based sampling mean that the findings cannot be considered generalisable to the British dairy farming population. The mean milking herd size in this study was not reflective of the mean milking herd size across England and Wales, which at the time of the study was reported as 151 and 147, respectively,[26] although it was comparable to other published studies exploring medicine use and recording methods in British dairy herds.[27,28] Aside from herd size, the diversity of participating farms and farmers was broadly comparable to the national picture.[29,30] The use of convenience sampling is also likely to have introduced motivation bias to the analysis, whereby motivation to participate may have depended on farmers' interest in the research topic or desire to express their specific opinions either positively or negatively.[31]

A further limitation is that a farmer with incomplete or incorrect data entries might have obtained a lower accuracy score than a farmer who failed to record an antibiotic treatment. Considering the importance of ABR, incomplete or incorrect data could be perceived as preferable to missing data in quantifying ABU. Comparison with veterinary sales data could have helped identify missing entries,[11,27] and review of daily diaries, which were used by all respondents, or use of bins to collect products used on-farm could be used to improve capture in future studies.[28] The scoring method gave equal weighting to all variables required under legislation[8] and the Red Tractor assurance scheme.[9] Statutory residue surveillance reports require animal ID to be recorded in non-compliance cases.[32] However, for antibiotic surveillance and food safety, accurate recording of the antibiotic quantity and name, withdrawal periods and dates fit for human consumption are of most importance. Therefore, further work could give increased weighting to such variables in the scoring method to differentiate farmers who accurately capture these data from those who have not complied. In addition, the scoring method had limitations in accounting for over- or underdosing, prolonged use, combined treatment, and dry cow treatments and calving dates. Further discussion of how these factors may have affected the scoring is provided in the Supporting Information.

The recording method is unlikely to be the only factor impacting recording accuracy. Further work to investigate other farm-associated variables would provide further insight into what influences accuracy.

20427670, 0, Downloaded from https://bvajournals.onlinelibrary.wiley.com/doi/10.1002/vetr.3505 by Test, Wiley Online Library on [11/10/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Additionally, recording software was dominated by one company in this study. Comparative analysis of accuracy between different software platforms could be conducted to see if the structure of one platform has an increased association with accuracy compared to others.

Improved software functionality, active discussion and engagement with industry and improved infrastructure to support dairy farmers in using software are crucial in developing a centralised ABU recording system. Stakeholder engagement needs to identify what information farmers would like in return for entering their ABU electronically. Previous work suggests that ABU data entry is seen as a task to demonstrate conformity to legislation and assurance schemes rather than providing value to farmers on herd health, giving little incentive to improve.[33] Continual monitoring by veterinary surgeons and milk buyers would act as a nudge and promote dialogue to address successes and concerns. Training and support should be provided for those lacking sufficient IT skills. As farmers already perceive their records to be accurate regardless of the method used, industry will need to encourage further uptake of electronic recording and drive the improvement of recording software.

AUTHOR CONTRIBUTIONS

Conceptualisation: Camilla Strang, Pablo Alarcon and Lucy Brunton. *Study design and methods*: Camilla Strang, Pablo Alarcon and Lucy Brunton. *Formal analysis*: Camilla Strang. *Interpretation*: Camilla Strang. *Data curation*: Camilla Strang. *Writing—original draft preparation*: Camilla Strang. *Writing—review and editing*: Camilla Strang, Lucy Brunton, Pablo Alarcon and Jacqueline Martina Cardwell. *Visualisation*: Camilla Strang. *Supervision*: Pablo Alarcon, Jacqueline Martina Cardwell and Lucy Brunton. *Project administration*: Camilla Strang and Lucy Brunton. *Funding acquisition*: Camilla Strang, Pablo Alarcon, Jacqueline Martina Cardwell and Lucy Brunton. All authors have read and agreed to the published version of the manuscript.

ACKNOWLEDGEMENTS

Many thanks to all the farmers who gave their time to partake in this study, Eamon Watson and colleagues at National Milk Records (NMR) and Alasdair Moffett and colleagues at Synergy Farm Health for their help with recruitment of farmers and feedback on methods. Camilla Strang was supported by an internal PhD studentship award from the Royal Veterinary College. Additional funding for farmer interviews was awarded by Antibiotic Research UK (grant number ANTSRG 01/2018).

CONFLICT OF INTEREST STATEMENT

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

DATA AVAILABILITY STATEMENT

The anonymised data presented in this study are available on request from the corresponding authors.

ETHICS STATEMENT

This study was approved by the Royal Veterinary College's Social Sciences Research Ethical Review Board (SR2018-1621).

INFORMED CONSENT STATEMENT

Informed consent was obtained from all subjects involved in the study.

ORCID

Camilla Strang https://orcid.org/0000-0001-8248-7470

REFERENCES

1. European Medicines Agency. Advice on implementing measures under Article 57(3) of Regulation (EU) 2019/6 on veterinary medicinal products—report on specific requirements for the collection of data on antimicrobial medicinal products used in animals. 2020 [cited 2020 Aug 9]. Available from: https://www.ema.europa.eu/en/documents/regulatory-procedural-guideline/advice-implementing-measures-under-article-574-regulation-eu-2019/6-veterinary-medicinal-products-report-format-data-be-collected-antimicrobial-medicinal-products_en.pdf
2. Veterinary Medicines Directorate. UK-VARSS 2014. UK veterinary antibiotic resistance and sales surveillance report. 2014 [cited 2020 Mar 19]. Available from: https://www.gov.uk/government/publications/veterinary-antimicrobial-resistance-and-sales-surveillance-2014
3. Veterinary Medicines Directorate. UK-VARSS 2015. UK veterinary antibiotic resistance and sales surveillance report. 2015 [cited 2018 Aug 17]. Available from: https://www.gov.uk/government/publications/veterinary-antimicrobial-resistance-and-sales-surveillance-2015
4. Veterinary Medicines Directorate. UK-VARSS 2016. UK veterinary antibiotic resistance and sales surveillance report. 2016. Available from: https://www.gov.uk/government/publications/veterinary-antimicrobial-resistance-and-sales-surveillance-2016
5. Veterinary Medicines Directorate. UK-VARSS 2017. UK veterinary antibiotic resistance and sales surveillance report. 2017 [cited 2018 Oct 26]. Available from: https://www.gov.uk/government/publications/veterinary-antimicrobial-resistance-and-sales-surveillance-2017
6. Veterinary Medicines Directorate. UK-VARSS 2018. UK veterinary antibiotic resistance and sales surveillance report. 2018 [cited 2020 Feb 24]. Available from: https://www.gov.uk/government/publications/veterinary-antimicrobial-resistance-and-sales-surveillance-2018
7. Veterinary Medicines Directorate. UK-VARSS 2021. UK veterinary antibiotic resistance and sales surveillance report. 2021 [cited 2022 Dec 7]. Available from: https://www.gov.uk/government/publications/veterinary-antimicrobial-resistance-and-sales-surveillance-2021
8. UK Government. The veterinary medicines regulations 2013: part 3. 2013. Available from: https://www.legislation.gov.uk/uksi/2013/2033/part/3/made
9. Red Tractor. Red Tractor assurance: dairy standards. 2023 [cited 2023 Jul 18]. Available from: https://redtractor.org.uk/our-standards/dairy/
10. APHA. Current number of live herds in England and Wales. Department of Epidemiological Sciences. 2018.
11. González SM, Steiner A, Gassner B, Regula G. Antimicrobial use in Swiss dairy farms: quantification and evaluation of data quality. Prev Vet Med. 2010;95(1–2):50–63.

20427670, 0, Downloaded from https://bvajournals.onlinelibrary.wiley.com/doi/10.1002/vetr.3505 by Test, Wiley Online Library on [11/10/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

12. Althubaiti A. Information bias in health research: definition, pitfalls, and adjustment methods. J Multidiscip Healthc. 2016;9:211–17.
13. Arla Foods and National Milk Laboratories. Treat, sleep, test, repeat. Testing for medicine residues—what we do, what we find, and the importance of antibiotic recording. CPD course material available from authors. 2018.
14. Food Standards Agency. Information and guidance on the testing of milk for antibiotic residues. 2015 [cited 2023 Apr 13]. Available from: https://www.food.gov.uk/sites/default/files/media/document/testmilkantibioticres.pdf
15. Tang PC, LaRosa MP, Gorden SM. Use of computer-based records, completeness of documentation, and appropriateness of documented clinical decisions. J Am Med Inform Assoc. 1999;6(3):245–51.
16. Tsai J, Bond G. A comparison of electronic records to paper records in mental health centers. Int J Qual Health Care. 2008;20(2):136–43.
17. Yadav S, Kazanji N, Narayan KC, Paudel S, Falatko J, Shoichet S, et al., Comparison of accuracy of physical examination findings in initial progress notes between paper charts and a newly implemented electronic health record. J Am Med Inform Assoc. 2017;24(1):140–44.
18. Doidge C, Dickie J, Lovatt F, Hudson C, Kaler J. Evaluation of the use of antibiotic waste bins and medicine records to quantify antibiotic use on sheep, beef, and mixed species farms: a mixed methods study. Prev Vet Med. 2021;197:105505.
19. Grimm P. Social desirability bias. Wiley international encyclopedia of marketing. Chichester: John Wiley & Sons; 2010.
20. Van De Mortel TF. Faking it: social desirability response bias in self-report research. Aust J Adv Nurs. 2008;25(4):40–48.
21. Braun V, Clarke V. Successful qualitative research. London: SAGE Publications; 2013.
22. Nederhof AJ. Methods of coping with social desirability bias: a review. Eur J Soc Psychol. 1985;15(3):263–80.
23. Kaner EFS, Haighton CA, McAvoy BR. "So much post, so busy with practice—so, no time!'': a telephone survey of general practitioners' reasons for not participating in postal questionnaire surveys. Br J Gen Pract. 1998;48(428):1067–69.
24. Jones-Bitton A, Hagen B, Fleming SJ, Hoy S. Farmer burnout in Canada. Int J Environ Res Public Health. 2019;16(24):5074.
25. Edwards PJ, Roberts I, Clarke MJ, DiGuiseppi C, Wentz R, Kwan I, et al. Methods to increase response to postal and electronic questionnaires. Cochrane Database Syst Rev. 2009;2009(3):MR000008.
26. AHDB. Average size of dairy herd in UK by country. 2019 [cited 2023 Apr 13]. Available from: https://ahdb.org.uk/dairy/uk-and-eu-cow-numbers
27. Hyde RM, Remnant JG, Bradley AJ, Breen JE, Hudson CD, Davies PL, et al. Quantitative analysis of antimicrobial use on British dairy farms. Vet Rec. 2017;181(25):683.
28. Rees GM, Barrett DC, Sánchez-Vizcaíno F, Reyher KK. Measuring antimicrobial use on dairy farms: a method comparison cohort study. J Dairy Sci. 2021;104(4):4715–26.
29. AHDB. UK milk yield. 2019 [cited 2023 Apr 13]. Available from: https://ahdb.org.uk/dairy/uk-milk-yield
30. AHDB. Optimal dairy systems. 2023 [cited 2023 Apr 13]. Available from: https://ahdb.org.uk/optimal-dairy-systems
31. Stratton SJ. Population research: convenience sampling strategies. Prehosp Disaster Med. 2021;36(4):373–74.
32. Veterinary Medicines Directorate. National statutory surveillance scheme for veterinary residues in animals and animal products: 2020. 2020 [cited 2023 Apr 13]. Available from: https://www.gov.uk/government/statistics/residues-of-veterinary-medicines-in-food-2020–2
33. Escobar MP. DEFRA report: perceptions and practices of farm record-keeping and their implications for animal welfare and regulation. 2015 [cited 2023 Apr 13]. Available from: https://www.researchgate.net/publication/283071541_Perceptions_and_practices_of_farm_record-keeping_and_their_implications_for_animal_welfare_and_regulation

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Strang C, Alarcon P, Cardwell JM, Brunton L. Assessing antibiotic usage data capture accuracy on dairy farms in England and Wales. Vet Rec. 2023;e3505. https://doi.org/10.1002/vetr.3505

20427670, 0, Downloaded from https://bvajournals.onlinelibrary.wiley.com/doi/10.1002/vetr.3505 by Test, Wiley Online Library on [11/10/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License