

1 Original Article

2 Can farmers reliably perform neonatal lamb post mortems and use
3 the results to influence their behaviours?

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17 Abstract

18 Neonatal lamb mortality constitutes a significant economic cost and
19 is an important welfare challenge. Despite compelling evidence for
20 reduction strategies and cost benefits associated with it, there has
21 been no documented trend in national reduction since the 1970's.
22 We aimed to evaluate whether a knowledge exchange solution can
23 be accurately used to define farm specific loss risks by training
24 farmers how to examine neonatal lambs post-mortem and follow a
25 basic framework to record and interpret common causes of
26 mortality. Finally, we used participatory rural appraisal to assess
27 some of the existing challenges to reducing lamb mortality. When
28 considering outcomes for specific post mortem questions, there was
29 87.5% agreement between veterinary and farmer answers and
30 82.3% of farmer diagnoses ($n=96$) agreed with the veterinary
31 conclusions. When merged with farmer performed post-mortems,
32 farm specific mortality pie-charts were developed to highlight the
33 variation between flocks and the necessity for flock specific advice.
34 Common challenges to reducing loss included level of labour, skill
35 set of labour, communication within teams and shepherds generally
36 considered post-mortems to be a valuable tool. We consider that
37 farmer PMs of lambs could be a tool for the veterinary-farmer team,
38 facilitating the communication of farm specific advice and
39 empowering farmers to effect positive change.

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42	<u>Keywords</u>
43	Knowledge exchange
44	Lamb mortality
45	Post-mortem
46	Farmer
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61 Introduction

62 Neonatal lamb mortality constitutes a significant economic cost, an
63 obstacle to achieving efficient and sustainable lamb production and
64 is an important welfare challenge (Binns *et al.*, 2002; Sawalha *et al.*,
65 2007; Dwyer, 2008).

66 Neonatal lamb mortality is defined as the death of lambs during the
67 first week of life with the predominant risk period being the first 48
68 hours. Overall lamb mortality between scanning and sale ranges
69 from 10-25% (Mellor and Stafford, 2004) but in the authors
70 experience, it can as high as 30-40% on some farms. Typically 5.9-
71 12.5% of scanned lambs are lost between 0-48 hours old (Binns *et*
72 *al.*, 2002). Key causes of neonatal lamb mortality include stillbirth,
73 hypoxia due to dystocia, starvation, hypothermia, injury secondary
74 to dystocia or mismothering, infectious disease such as watery
75 mouth (Dwyer, 2008).

76 Risk factors leading to these causes of deaths include low birth
77 weight, high birth weight, poor maternal body condition, lamb
78 vigour at birth, underlying deficiency i.e. selenium or iodine,
79 dystocia, ewe with poor mothering ability, poor hygiene (Mellor and
80 Stafford, 2004). Multi-level modelling has identified farm and
81 management risk factors which are linked to increased level in lamb
82 mortality such as outdoor lambing, less frequent renewal of bedding
83 in pens, larger flocks and flocks with higher replacement rates.
84 Factors such as housing ewes and supplementing thin ewes were
85 found to be protective (Binns *et al.*, 2002). Experience of the

86 shepherd, feeding frequency, suckling assistance provided and use
87 of lambing pens were found to be protective in an additional model
88 (Holmoy *et al.*, 2012).

89 Targets for lamb mortality for a lowland flock should be less than
90 14% between scanning and sale, made up of 6% from scanning to
91 birth, 6% from birth to turnout and 2% from turnout to sale (EBLEX
92 Manual, 2015).

93 In 2014 within a large farm animal practice in South West England, a
94 lamb mortality survey of commercial flocks measured total lamb
95 mortality between scanning and weaning, with the practice median
96 recorded as 10.4% ($n=30$, range= 4.4%-20.8%) (EG personal
97 communication). Losses before turnout i.e. including pre-lambing
98 and peri-lambing mortality represented the largest loss period in
99 most flocks. Few flocks could attribute causes of loss to those lambs
100 not surviving to weaning through their pre-existing recording
101 methods.

102 The variation in lamb losses demonstrated both in peer reviewed
103 literature and in commercial flocks in this practice-based survey,
104 highlights that low levels of lamb loss are achievable, but despite
105 this and mounting evidence of causes of lamb mortality, compelling
106 evidence for reduction strategies and cost benefits associated with
107 it, there has been no documented trend in national reduction in the
108 past 40 years (Dwyer *et al.*, 2016).

109 Possible reasons cited for this lack of reduction are suggested in the
110 literature to be (a) lack of farm specific solutions, (b) dismissal of
111 research results by commercial farmers due to use of non-
112 commercial flocks in studies, (c) difficulty in applying the evidence
113 base to commercial flocks given the complex nature of mortality or
114 finally (d) lack of communication of the evidence base by advisors to
115 the farmers (Dwyer *et al.*, 2016).

116 This work also suggested that farmers felt 'powerless' to effect
117 change and reduce losses within the 48 hours of life in lambs and
118 prefer to divert resources to latter stages of production where their
119 efforts may be perceived as more effective (Dwyer *et al.*, 2016).

120 Other challenges to loss reduction could be perceived size of
121 investment in labour and resource necessary to reduce losses and
122 lack of perception of the pre-existing scale and cost of lamb
123 mortality to a sheep business.

124 The variation in losses observed in the 2014 practice based survey
125 suggested that generic lamb mortality advice has limited value when
126 applying to sheep flocks, given (a) the range in diverse systems and
127 (b) the diversity in main causes and timings of lamb losses. For
128 example, not all flocks examined experienced peak lamb loss in the
129 neonatal period and with post-turnout losses more significant for
130 some flocks.

131 Data collection on farm or lack thereof is often cited as a challenge
132 for quantifying level of and causation of lamb mortality at all stages
133 of production. The practice survey examined scanning and

134 movement record data to compare potential lambs available for sale
135 and actual number sold or retained within the flock. Mid production
136 cycle figures such as first numbers at first gather may enable crude
137 assessment of specific phases of loss, but suspected cause of death
138 is often challenging to obtain from flocks unless there is pre-existing
139 farmer motivation to record. Furthermore, in our experience, unless
140 there is a substantial increase in the level of morbidity and mortality
141 in lambs, veterinary surgeons are rarely asked to routinely examine
142 neonatal lambs post-mortem, presumably because of (a) cost, (b)
143 logistics and time of taking lambs to a collection centre and/or (c)
144 lack of perceived benefit.

145 We hypothesised that equipping sheep farmers with skills and
146 resources to enable them to define the specific causes of neonatal
147 mortality on their own units can lead to engagement and
148 empowerment of sheep farmers to effect change and appropriate
149 targeting of advice by their advisor and channelling of resources to
150 reducing neonatal mortality.

151 The objectives of this study were:

- 152 1. To evaluate whether a knowledge exchange solution can be
153 accurately used to define loss risks by training farmers how
154 to examine neonatal lambs post-mortem and follow a basic
155 framework to record common causes of mortality
- 156 2. To work with farmers and using the results to build up a
157 farm specific picture of causes of mortality

158 3. To enable farmers to use this evidence to make changes
159 that reduce the risk leading to avoidance lamb mortality.

160

161 We measured our success in achieving these objectives by
162 answering the following questions:

163 a) Once trained by a veterinary surgeon, can sheep farmers
164 accurately diagnose common causes of mortality in neonatal
165 lambs?

166 b) What were the common causes of lamb loss on each farm
167 and how did these differ between units?

168 c) Did the farmers involved in the project use their findings to
169 effect change?

170 d) How has the programme changed attitudes and motivation?

171 Materials and methods

172 *Flocks*

173 Five flocks were recruited to participate in the project. The flocks
174 were convenience selected based on an expressed interest by the
175 shepherds to target lamb mortality as one of their annual key
176 performance indicators, proximity to a central veterinary practice
177 (within 40 miles of Synergy Farm Health Ltd), defining themselves as
178 commercial sheep flocks i.e. lamb sales were a significant portion of
179 farm revenue and lambing in Springtime. Four of the flocks were
180 within Dorset and the fifth was in Somerset.

181 Ewe numbers in the flocks ranged from 250-2500 with a range of
182 breeds and systems i.e. entirely outdoor lambing Romney flocks,
183 indoor/outdoor composite units based on Mules with twins
184 outdoors, triplets and singles indoors to facilitate wet fostering and
185 finally, entirely indoor lambing units lambing Lleyns (see table 1).The
186 flocks were visited between three and six times over lambing
187 depending on their duration and peaks in lambing.

188 *Study design*

189 The five shepherds participated in a one day practical course
190 delivered by veterinary surgeon investigator and one of the authors
191 (EG) who has recognised training qualifications (Foundation
192 Certificate in Staff Development and Certificate in Training &
193 Occupational Learning). The farmer training course covered the
194 background to lamb mortality including its common causes and
195 financial implication, common zoonotic challenges when working
196 with lambing sheep and relevant additional health and safety risks
197 associated with performing a post-mortem (PM) examination of
198 peri-natal lambs i.e. pre-natal abortions or post-natal losses. Control
199 of Substances Hazardous to Health (COSHH) datasheets were
200 presented for recommended disinfectants.

201 The importance of sample selection was also explained to
202 participants with farmers recommended PM animals with a known
203 clinical history and less than 24 hours deceased. Disposal of
204 carcasses via approved routes i.e. via fallen stock for incineration
205 was recommended. The farmers also took part in a practical session

206 at a local fallen stock yard (Secanim Ltd, Dorset) where PM
207 techniques were demonstrated on fresh samples and the shepherds
208 examined further lambs whilst being supervised. The framework for
209 PMs used was an adapted version of a lamb PM form (AHDB Beef
210 and Lamb; see supplementary material).

211 The flocks were then visited weekly throughout lambing up to a
212 maximum of six visits and a single investigator (EG) observed farmer
213 performed PMs on lambs which had died within the previous 24
214 hours. Both the shepherd and EG completed their PM form in
215 isolation with results discussed after form submission. These results
216 were collated and compared and submitted into Microsoft Excel
217 2013. The data was checked for errors and then univariate binary
218 analysis was performed in R (R Core Team, 2013) with the
219 significance level set at $p < 0.05$.

220 Shepherds were also asked to perform PMs on lamb in the interval
221 between veterinary visits with the results submitted to the project.

222 After initial analysis of comparative PMs, the veterinary causes of
223 death were combined from “comparison PMs” were combined with
224 the farmer performed PMs (completed in absence of vet between
225 visits) to produce a farm specific pie chart for cause of death.

226 *Participatory Rural Appraisal*

227 Dwyer *et al.*, 2016 considered the obstacles to effecting change in
228 reduction of lamb mortality on farm. Participatory Rural Appraisal
229 (PRA) is a recognised approach using systematic and structured

230 activities to gain understanding of rural resources and attitudes
231 from the local people (FAO website, Chambers, 1994). It has been
232 used extensively in the developing world by non-government
233 organisations (NGOs) to facilitate delivery of targeted, effective and
234 realistic solutions to local people. PRA by definition is designed to be
235 a flexible interviewing and engagement exercise designed to
236 empower individuals who are likely to effect change, with the aim of
237 arriving at sustainable local actions. Semi-structured interviews
238 (SSIs) are often used to facilitate this (Grandstaff and Grandstaff,
239 1987, van Teijlingen, 2014). A single investigator (EG) facilitated the
240 SSIs which were recorded and ranged from 30 minutes to 2 hours.

241 During the SSI, the shepherds were asked to participate in a series of
242 exercises relevant to lamb mortality:

- 243 (a) To write a list of the tasks necessary on a typical day during
244 lambing
- 245 (b) To place dried beans next to the jobs they felt took the most
246 time.
- 247 (c) To rearrange the beans and place them next to the jobs that
248 they felt kept the most lambs alive. This list was also
249 photographed (see figure 1).

250 They were also questioned during the SSI about their attitudes
251 towards PMs, the challenges for lamb mortality on their own farms
252 and how PMs had influenced practices on farm. Finally, they were
253 asked to rank risks for lamb mortality on their own farm on sliding

254 scales of 0-10 i.e. 0 no threat to lambs on the unit to 10, a very
255 significant threat to lambs.

256 Interviews were recorded and transcribed into Microsoft Word
257 2003. The interviews were analysed using thematic analysis
258 techniques with the transcripts coded, unitized for common
259 concepts and then compared using the constant comparative
260 technique (Maykut and Morehouse, 2001).

261 Results

262 *Quantitative analysis*

263 A total of 96 lambs were examined by PM across five flocks in the
264 presence of the investigator and an additional 40 lambs examined
265 by farmers directly.

266 From this table we can see both variation between questions and
267 variation within questions between farmers. When considering
268 specific questions, correct answers per question ranged from 80.2%
269 of answers given up to 97.9% agreement with the veterinary
270 surgeon. Overall, farmers gave 87.5% correct answers to the PM
271 questions.

272 When considering farmer answers to specific questions there was a
273 high degree of correlation between vet and farmer answers.

274 Noticeably lower correlation values included for flock A agreement
275 with the vet in 72.3% of cases when considering how many lambs
276 had renal fat present and for flock B with agreement of just 71.4% of

277 answers with the vet when asked if there was evidence of fluid in
278 tissues around the head.

279 When considering all the questions answered, farmers' overall
280 scores all ranged from 88.9% of correct answers up to 96.8%.

281 Ultimate diagnosis and the individual farmer results were
282 considered and are presented in table 3, showing that overall, 82.3%
283 of farmer post-mortems agreed with the veterinary conclusion. One
284 flock achieved 100% of correct diagnosis but there were a small
285 number of comparative PMs performed on this farm.

286 When looking at type of diagnoses reached, the proportion of
287 correct diagnosis were classified relative to the veterinary confirmed
288 cause of diagnosis (see figure 2). We can see that the largest errors
289 were made when the veterinary verdict was "no diagnosis" ($n=16$
290 total) and "starved" ($n=21$ total).

291 *Common causes of mortality*

292 Given the level of agreement between vet and farmer diagnosis, a
293 pie chart was generated for each flock showing common causes of
294 death. (See figures 3a, b, c, d, and e) and presented to flocks during
295 their semi-structured interviews.

296 *Qualitative analysis*

297 After transcription of the semi-structured interviews, they were
298 coded according to key themes identified during transcription. Key
299 themes identified when considering lamb mortality were: (1)

300 responsibilities during lambing (2) provision of skilled labour (3)
301 team dynamics (4) the advantages of PM examination on farm (5)
302 the challenges of PM examination on farm (6) changes made as a
303 result of PMs.

304 *The responsibilities of lambing*

305 When shepherds were asked to list their task lists during a typical
306 lambing day, there was huge variation between flock types and
307 additional enterprises/responsibilities on farm. Having initially been
308 asked to rank tasks based on their duration, they were then asked to
309 revise the ranking based on how important the relevant task was in
310 keeping lambs alive. This revision highlighted for flocks (a) time-
311 consuming jobs which did help keep lambs alive i.e. teaching
312 students, checking colostrum status, feeding ewes (b) time
313 consuming jobs which did not help keep lambs alive and i.e. tagging
314 and recording lambs, checking cattle (c) jobs not currently
315 consuming a lot of time but which could help keep lambs alive, for
316 example treatment of pre-parturient lame ewes in the lambing
317 shed. Typical statements included:

318 “In my role we are also talking about
319 coordination of contractors at that time of
320 year we are trying to get corn in the
321 ground.”

322 “Did we put enough labour to it? There
323 was a lot of stock about. We still had fat

324 hogs about which needed drawing for
325 abattoir. Should we get to the point of
326 having minimal stock at Spring?"

327 "It's surprising how long the dogs take!"

328 The role of colostrum management in reducing lamb mortality was
329 repeated in multiple interviews. The importance of colostrum
330 management and diagnosis of starvation and mismanagement was
331 also coupled with the importance of stockmanship:

332 "I check the colostrum of every lamb, but
333 you've got to be able to spot how a lamb
334 behave and moves too".

335 The desire to have more lambs reared was communicated by all
336 flocks as a key driver of improving margins per ewe. However, how
337 to achieve this divided opinion, for example when considering
338 whether emphasis should be placed on increasing scanning or
339 increasing rearing percentage:

340 "No I am happy with scanning but I would
341 like to think 1.75 should be doing better
342 than that, lots claim can scan higher. I
343 know that's not desirable because you end
344 up with lots of triplets and I am not
345 wanting that but, I want to be producing
346 lambs and not keeping sheep for the fun

347 on it. The way forward is using our building
348 and resources to the best of its ability”.

349 The drain of time resources that small lambs place on the shepherds
350 was observed and discussed in all systems. They were considered to
351 be unrewarding and where possible, flock health planning and
352 fertility management should be used to avoid small lambs.

353 “The problem with triplets is every single
354 one needs assistance. It’s not like twins”.

355 “Breeding these small lambs is a wastage,
356 it’s a wastage of time and resources put
357 into them!”

358 *Provision of skilled labour*

359 Provision of skilled labour and staffing levels was discussed in all five
360 interviews irrespective of indoor or outdoor lambing models.

361 The role of less experienced veterinary or agricultural students in
362 the lambing sheds was evident from all interviews. However, this
363 leads to challenges that may have contributed to lamb mortality.

364 “It is frustrating in some cases [student
365 labour] might be a help, because you have
366 those pair of eye, or you have people who
367 feed individual pens. You know, I send
368 people around to check pens, to get sheep
369 up, get lambs up, check they are all ok,

370 check mouths, just occasionally they might
371 miss something, so you are relying on
372 people who are training to learn, and part
373 of their learning is that they are going to
374 make mistakes that you are going to have
375 to correct which can be to your
376 detriment!"

377 Availability of skilled relief during lambing was discussed by multiple
378 shepherds as was the challenge of delegating jobs which required an
379 inherent skill and stockmanship level. The lack of such relief either
380 through lack of recruitment to the team or availability in the job
381 market, put pressure on shepherds wishing to delegate aspects of
382 their responsibility lists. Phrases such as 'not for a novice', and 'it's
383 not the sort of thing I could just get Joe Bloggs to do' were used.

384 When asked whether student teaching does save lambs, several
385 participants agreed that it did due to increasing skill levels in those
386 individuals enabling them to facilitate lamb management:

387 "Communicating to student sometimes
388 does keep lambs alive. I think that's where
389 I am not spending enough time".

390 In general flocks were however sympathetic to the educational
391 needs of students and the role they play in their systems:

392 "I always say you learn by making mistakes
393 but by seeing good things as well".

394 However, an interesting counter-argument presented when
395 discussing levels of supervision and the possibility of over-
396 supervision:

397 “Well you could argue is too much
398 supervision *chuckles* just lots of
399 disturbance, not like a normal farm- we
400 have kids running around pens, I am trying
401 to think what to call it, unskilled
402 supervision.”

403 *Team dynamics*

404 The challenges of team communication during lambing was a
405 common theme in all five interviews and ranged from mismatched
406 input expectations between managers and assistants to individual
407 participants’ frustration with the lambing period if lambs died during
408 assisted lambing.

409 The importance of a team strategy prior to lambing was
410 acknowledged by managers:

411 “My intentions were that full time staff
412 were going to have a sit down and
413 structured talk about what we wanted and
414 what we wanted to achieve and that was
415 important and it didn’t happen.”

416 “I think communication within a big team
417 who might be around when things are

418 happening [is important]. They are
419 constantly being told. It's the starved ones
420 from me which are quite annoying for
421 me!"

422 It was evidence that the aforementioned availability and skill level of
423 relief labour was often an obstacle when shepherds were trying to
424 achieve targets as was incomplete communication of protocols and
425 expectations within lambing teams.

426 *The advantages of PM examination*

427 On the whole the flocks perceived that there was a value in on farm,
428 farmer delivered PMs generating dynamic information in the midst
429 of mortality threats on farm. There was a consensus between flocks
430 that the knowledge gained by performing PMs could contribute
431 towards improving conditions for lambs. A typical response
432 included:

433 "Well I suppose in a way, post morteming
434 lambs, doesn't keep them alive. Well does
435 it? Because we are learning about things,
436 learning about what's killing them!"

437 "You could argue that if you did a few
438 more post mortems if might show you
439 what your problems are which are creating
440 your problems during the day".

441 The value of PMs as an educational tool for use within teams of
442 shepherding staff and as a visual tool to demonstrate relevance of
443 protocols such as feeding hungry lambs that could be used as an
444 anonymous tool. Finally, its role as a teaching tool for younger
445 inexperienced shepherds was suggested.

446 *The challenges of PM examination*

447 Typical obstacles to conducting PMs were time availability. Flocks
448 were asked about typical time taken to perform a lamb PM on farm.
449 This varied between flocks but ranged between 4-20 minutes. One
450 commented:

451 “You do get to a point, where to start with
452 I was being quite neat but you get to a
453 point where you cut it open and have a
454 look and then having a think!”

455 However, an additional consensus was that it often featured lowly in
456 the priorities of the daily ‘jobs lists’ despite the apparent value of
457 the additional information:

458 “Everything had to come before, all stuff
459 that needing saving”

460 Furthermore, there was often a desire by flocks to fit in more PMs
461 but finding time was often challenging:

462 “And then there were often times when I
463 wanted to but sometimes a couple of days
464 went by”.

465 “The actual physical 30-20 minutes but all
466 of a sudden you have people coming in
467 saying ‘Can you come and help me?’ and
468 then I haven’t [got time]!”

469 *Changes made*

470 Flocks commented that they had made changes to management
471 based on results found doing PMs on farm:

472 “Anything we changed this year? The
473 biggest single change was having the lamb
474 milk machine going and orphan lambing
475 coming own to either the hot boxed or
476 under the lamps..... there was lot more
477 input directed at orphan lambs this year!”

478 One flock experienced an infectious lameness outbreak in housed
479 ewes with contagious ovine digital dermatitis (CODD). When
480 discussing their PM results and risk for lamb mortality on their own
481 unit, lameness management was a central theme in the discussion.
482 When asked if infectious lameness management has a positive
483 effect on lamb mortality diagnosed on their farm the impact on ewe
484 health and welfare and subsequent lamb survival was discussed:

485 Participant 1: “Yes it does a bit doesn’t it,
486 because they produce more milk!”

487 Participant 2: “Well why didn’t we have
488 any beans on there before we started?”
489 (*Referring to time expenditure in initial*
490 *exercise*)

491 There were scenarios where despite evidence from the PMs,
492 additional inputs were not possible. For example when asked about
493 how the PM results could be used to influence management
494 practices next year, the responses were:

495 “We could look around more, but I’d never
496 stop. Ideally we’d employ an extra person
497 but there is a cost!”

498 “But it is also having a system which allows
499 minimal input and minimal labour to help a
500 lot of sheep that’s the design of the
501 system, watching ewes, pens and turning
502 out, and feeding obviously.”

503 Whilst dynamic information did enable flocks to monitor ongoing
504 and changing threats to lamb mortality, there was a situation where
505 there may have been over interpretation of results. When asked
506 what was changed as a result of accumulating data:

507 “And one of the things we changed more
508 this year, was we intervened more with
509 lambing, because of what we had seen...”

510

511 Discussion

512 Dwyer *et al.* (2016) identified the challenge for commercial sheep
513 flocks in implementing and effecting change on commercial sheep
514 flocks when considering lamb mortality. The lack of progress
515 reported over the past forty years represents a substantial threat to
516 ongoing animal welfare and the profitability of sheep flocks. To the
517 authors’ knowledge, this is the first study on sheep farms to explore
518 farmer’s beliefs about the limitations of their own system and likely
519 effects of change, (although other examples exist in other fields
520 such as bovine lameness (Main *et al.* 2012)) and represents a novel
521 knowledge transfer based solution to the investigation of lamb
522 mortality.

523 Our main objective was to assess the reliability of farmer PM results
524 by comparing anonymous farmer and veterinary surgeon
525 completion of a PM report when observing the same lamb.

526 Challenges in obtaining this data included availability of suitable
527 carcasses on dates of visits i.e. due to lack of carcasses, lack of
528 availability of fresh carcasses or predation of outdoor lambs.

529 Additionally farmers commented in the SSI that they had found
530 limited time opportunities during lambing to perform lamb PMs and

531 had placed more emphasis on 'living lambs' although they
532 recognised the value of the information obtained by PM. In the
533 authors' opinion, as many lambs as possible should be examined by
534 post-mortem as possible in order for results to accurately reflect the
535 risks to lambs on farm. Other authors have suggested that 10% of
536 neonatal lamb losses should be examined by post-mortem (Fragkou
537 *et al.*, 2010).

538 When performing comparative PMs, farmers often queried
539 outcomes or unusual presentations after submission of individual
540 PM reports and therefore there is likely to be a contribution of this
541 continued knowledge exchange throughout the project in
542 comparison to the situation where farmers are not routinely visited
543 by a veterinarian through the lambing period. The effect of this
544 cannot be easily quantified due to small numbers of PMs and the
545 variation of presentations at each visit.

546 Signalment, accurate weights and history of dead lambs was not
547 considered in our analysis and was often absent on the farmer-
548 derived PM reports accumulated in the absence of a vet. Many
549 preferred to include small, medium or large when assessing lamb
550 size. In our opinion this does not negate the value of the PMs but
551 may limit the accurate assessment of pathogenies of lesions, for
552 example where no age at death is available for a lamb that died as a
553 result of neonatal scouring. Likewise, it may limit interpretation of
554 the success of interventions.

555 When examining farmer accuracy in answer specific questions about
556 an individual lamb, they were largely consistent and successful (see
557 table 3). Some parameters proved more challenging than others and
558 in our opinion the subjective nature of some questions led to these
559 errors. For example meconium staining was the subject of debate
560 and its relevance for ultimate diagnosis is not apparent. Secondly
561 there were disagreements on presence and absence of peri-renal fat
562 (see figure 4). This brown fat is typically considered to have
563 disappeared within 6 hours of birth but there were older lambs
564 where this was still apparent. As a consequence, some farmers may
565 have been dissuaded from concluding that starvation was the cause
566 of death, especially where time of death had not been recorded.
567 This may account for the errors observed in this diagnosis category
568 (see figure 2).

569 The largest proportion of errors occurred when examining the navel
570 for evidence of dryness which is not likely to be significant for
571 drawing ultimate diagnoses. However, missing the evidence of
572 broken ribs and clots is likely to skew diagnosis (see figure 5 showing
573 free blood in abdomen secondary to liver rupture, figure 6 showing
574 broken ribs).

575 The disagreements between lungs floating and not, in the
576 investigators' opinion, is likely to be a recording-related error rather
577 than misinterpretation. The phrasing of the question on the original
578 and adapted questionnaire is ambiguous and would need to be

579 revised before making available to farmers for ongoing recording
580 purposes.

581

582 When considering final diagnosis, 82.3% of farmer PMs reached the
583 same diagnosis as the veterinary surgeon and individual farmers
584 ranged from 79.2-100% correct. It should be noted that the farmer
585 achieving 100% did the smallest number of post-mortems. The
586 largest errors were in “no diagnosis” i.e. where farmers stated a
587 cause of death but the veterinary surgeon did not think that one
588 was apparent, and secondly for ‘starvation’. High errors in assessing
589 remaining brown fat levels may account for flocks failing to treat
590 starved lambs. In our opinion the farmers were successful in
591 diagnosing cause of death in lambs but that ongoing validation is
592 necessary to ensure common diagnoses are not being overlooked.

593 Our second objective was to evaluate common causes of death in
594 neonatal lambs and to observe how these varied between different
595 units. This was achieved by merging the veterinary diagnoses from
596 joint PMs and farmer diagnoses from PMs performed without
597 supervision. The combined results reflect previous PM work in the
598 UK (Green and Morgan, 1993) with common diagnoses featuring
599 such as ruptured liver, broken ribs and “hung lambs” with oedema
600 of the neck having presented with an anterior, dorsal presentation
601 with no forward presented legs. We can see clearly in figure 3 that
602 there is significant variation in cause of lamb deaths between indoor
603 and outdoor units. There is also variation in causes of death

604 between similar units i.e. the two indoor lambing flocks with
605 traumatic injuries such as broken ribs and ruptured livers more
606 significant in flock A than flock E. The infectious disease profile e.g.
607 presence of watery mouth also varied between units. A clear
608 difference is the significance of starvation for the entirely outdoor
609 lambing flocks in comparison with other systems.

610 This variation in causes of death in lambs between units supports
611 previous suggestions that generic lamb mortality advice is not
612 appropriate for flocks (Dwyer *et al.*, 2016). For composite flocks i.e.
613 indoor and outdoor lambing, it was not possible to establish
614 whether lambs were indoor and outdoor in origin and therefore it is
615 likely that both contribute to the flock pie charts. We suggest that
616 when focusing specific investigations, origins of the lamb is essential
617 information for such flocks and should be recorded.

618 Our third objective was to consider whether results obtained could
619 be used to effect change on participating flocks and to consider
620 owner attitudes and motivations for change. When asking farmers
621 to comment on the combined diagnosis during the semi-structured
622 interviews, resource availability both for (a) fitting in PMs or (b)
623 implementing change, was often a limiting factor and varied
624 between farms. This supports Dwyer *et al.* (2016) emphasis on the
625 importance of flock specific advice based on known farm specific
626 risks.

627 When considering changes made during lambing or to be made for
628 subsequent years, one flock acknowledged that investment in

629 additional labour could reduce their lamb mortality. The role of
630 students in lambing systems was evident and there was
631 acknowledgement of the importance of investing time in training
632 individuals and the benefit they could have in reducing lamb
633 mortality. Many flocks find it challenging that students often arrive
634 on farm at the commencement of the lambing period and leave at
635 the time they have developed necessary stockmanship skills. As a
636 consequence one flock involved was considering hiring a relief
637 shepherd/night lamber during lambing to facilitate improved
638 supervision and availability for student training.

639 Whilst we were largely satisfied that farmers had correctly
640 diagnosed and interpreted causes of lamb death, we did observe
641 some misinterpretation. One flock recorded multiple lambs with
642 broken ribs and/or liver capsule rupture. As a consequence they
643 opted to intervene more quickly when ewes were lambing, but did
644 not observe a reduction in the presence of pathology. On debriefing,
645 we were concerned that these lambs were being assisted before
646 ewes had had sufficient opportunity to dilate (especially where large
647 single lambs or backwards lambs) and that the preferred action
648 would have been to observe ewes and give them longer prior to
649 intervention with strict standard operating procedures for when and
650 how to intervene. As a consequence of this debrief, such operating
651 procedures are in place for the next lambing. However this
652 highlights the importance that farmer-performed lamb PMs are not
653 used in isolation without technical support and advice from the
654 flock's routine veterinary surgeon.

655 We consider that, in conjunction with appropriate supportive
656 advice, that PMs could form a tool for veterinary engagement
657 through training, ongoing support and flock health planning to
658 empower flocks in generating their own reliable, farm specific data.
659 A basic understanding of common causes of lamb mortality such as
660 starvation will enable farmers to have an immediate impact on
661 operating procedures on farm.

662 It should be acknowledged that this this study only examined five
663 flocks with moderate-high veterinary engagement and a pre-existing
664 commitment to reducing lamb mortality. However, it could be
665 considered a novel strategy for flock engagement and mortality
666 investigation.

667

668 Conclusions

669 The role of the veterinary surgeon in sheep enterprises is dynamic
670 and evolving especially with the movement towards flock health and
671 production management. As observed in other areas of farm animal
672 medicine, we must embrace our diverse role as vets and consider
673 what alternative inputs we can have on farm i.e. though training and
674 dynamic interaction with farms.

675 Veterinary surgeons should not be threatened by this involvement
676 of farmers in the decision tree as is currently embraced in many
677 other aspects of farm animal practice given the lack of protection
678 conferred by the Veterinary Surgeons Act over roles previously

679 considered the remit of veterinary surgeons alone. For many
680 veterinarians engagement in large numbers of lamb post-mortems
681 in not a reality and pre-existing pro-forma decision trees are
682 available in the public domain (AHDB, 2016). This should be seen as
683 an opportunity for engagement in training and with producers.

684 We consider that farmer PMs of lambs could be a tool for the
685 veterinary-farmer team, facilitating the communication of farm
686 specific advice and empowering farmers to effect positive change.

687 Conflict of interest

688 The authors declare they have no competing interests.

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748

749 Captions

750 Table 1: A summary of the flocks recruited to the project including
751 breeds on farms.

752 Table 2: A table showing the proportion of correct answers by flock
753 to post-mortem specific questions when considering comparative
754 post-mortem examinations.

755 Table 3: A table to show the percentage agreement in diagnosis
756 between farmers and vet observing the same post-mortem

757 Figure 1: An image showing a section of a farm produced “jobs” list
758 complete with examples of beans assigned to each task type.

759 Figure 2: A graph to show proportion of correct diagnosis from
760 farmers, relative to veterinary diagnoses for each diagnosis type.

761 Figure(s) 3 (a-e): Flock specific pie charts with data merged from
762 farmer-vet comparative PM’s with farmer PM’s. Where comparative
763 PM’s, if farmer and vet disagreed the vet diagnosis was utilised

764 Figure 4: An image showing an example of peri-renal fat present in a
765 neonatal lamb

766 Figure 5: An image showing free blood in the abdomen of a neonatal
767 lamb due to liver capsule rupture.

768 Figure 6: An image showing unilateral broken ribs in a neonatal

769 lamb.

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