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Integrating data of veterinarians' practices in assessing the cost effectiveness of three components of the bovine tuberculosis surveillance system by intradermal tuberculin testing in French cattle farms through a scenario-tree approach

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ABSTRACT

Disease surveillance systems' effectiveness relies on participants following prescribed practices. We developed a general method to improve a previous cost-effectiveness evaluation of three French screening program protocols for bovine tuberculosis (bTB) to account for the practices of participants by scenario tree modelling. This method relies on: 1) semi-directive interviews of participants to identify the variability of practices and potentially influential factors, and to understand the sociological context; 2) a quantitative survey, based on multiple-choice questions, to quantify various practices and identify significantly influential factors by multivariable regression analyses; 3) addition of the scenario-tree nodes corresponding to the practices and their influential factors and configuration of the new limbs according to the data of the quantitative survey.

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We used this approach to integrate data concerning veterinary practices and identify some failures to conform to regulatory guidelines regarding intradermal cervical comparative tuberculin test (SICCT) (testing and notification of non-negative results). Such nonconformities appeared to be mainly caused by cattle restraint issues and the perception of veterinarians of the bTB control program. Indeed, their perception of that program significantly influenced veterinarians' practices. We modelled the influence of the SICCT practices on the SICCT results. The incorporation of these data led to a major decrease of the herd sensitivity estimations relative to the previous assessments that did not incorporate data of practices (15% to 42% decrease). This result shows the important impact of veterinarians' practices and their influencing factors (such as perception of the bTB control program) on the effectiveness of the surveillance system.

KEYWORDS: practices, scenario tree, bovine tuberculosis, sensitivity, surveillance, intradermal tuberculin test

INTRODUCTION

Quantitative evaluation methods to evaluate the effectiveness of animal surveillance systems are well established. Indeed, methods, such as scenario tree modelling, have been formally described (Martin et al., 2007) and used in many surveillance system evaluations (Hadorn et al., 2009; Christensen et al., 2011; Hénaux and Calavas, 2017). These methods usually use epidemiological and, for cost-effectiveness evaluations, economic data. In parallel to the development of these methods, the acceptability of surveillance systems and the corresponding practices by the participants has been studied. Indeed, the effectiveness of disease surveillance systems relies mostly on the willingness of their actors to participate and follow prescribed practices (Pfeiffer, 2006). This willingness depends in part on the epidemiological context of the considered disease and the perceived severity and consequences of it (Brennan et al., 2016). Thus, studies have evaluated the

willingness of actors to follow prescribed practices (Sayers et al., 2014; Delabouglise et al., 2017 ; Pham et al., 2017). In some of them that used participatory epidemiology, actors are directly implicated, allowing them to identify motivational levers and obstacles to the effectiveness of surveillance systems and to sometimes suggest means to improve them (Catley, 2006; Delabouglise et al., 2017). In the past few years, the increase of published studies investigating the influence of the practices and perceptions of veterinarians and farmers on the effectiveness of disease control programs shows the growing interest in these factors (O'Hagan et al., 2016; Schulz et al., 2016; Ciaravino et al., 2017; Rivière et al., 2018). Nevertheless, most of these studies were qualitative and even quantitative ones have never combined data concerning the practices of actors and associated influential factors with standard epidemiological and economic data in a global quantitative evaluation of disease control systems.

Here, we aimed to develop a method to integrate data concerning actor practices (in our example, the practice of SICCT and notification of non-negative results by veterinarians) within our research on bovine tuberculosis surveillance (bTB) in cattle and the factors that influence them in scenario-tree modelling, the quantitative method we used for the efficiency assessment. Indeed, we first evaluated the cost-effectiveness of periodic screening on French farms by scenario-tree modelling (Poirier et al., 2019). This first evaluation allowed us to identify the most efficient protocol for each type of herd (according to production type, herd size, and herd turnover) but accounted only for epidemiological and economic data. However, other factors, such as how the intradermal cervical comparative tuberculin test (SICCT) is practiced by the veterinarians or their willingness to notify authorities of non-negative results of the SICCT (which depends on his perception of bTB surveillance and control programs) could influence the effectiveness of bTB surveillance on French farms. The community of bTB researchers and surveillance managers empirically recognize the influence of such factors on bTB surveillance of cattle. In addition, the particular French context, in which private veterinarians are empowered by the State to perform regulatory controls on their own customers' farms in a low bTB prevalence context, could potentially lead them to less frequently notify the authorities of non-

negative SICCT results. Indeed, they may want to avoid being responsible for negative sanitary and economic consequences for their customers' farms, as false-positive results are currently frequent in the French epidemiological context and trigger serious restrictive measures, such as the ban of selling animals. In other European countries, researchers have begun to semi-quantitatively study veterinary SICCT practices (Humblet et al., 2011; Ciaravino et al., 2017). We also investigated these factors in France and strengthened the approach by integrating data concerning veterinary practices and the most influential field factors (determinants) in our quantitative evaluation of the bTB surveillance system component in cattle farms. Here, we describe the method we developed for integrating qualitative data concerning actor practices into scenario-tree modelling and its use in the evaluation of bTB surveillance by periodic screening of French farms. The use of this method will result in a more realistic estimation of the cost-effectiveness of the periodic screening component of the French bTB surveillance system to identify issues related to this component and suggest operational solutions for its improvement.

MATERIALS AND METHODS

1. The regulatory bTB surveillance protocols studied

In a previous study, we developed scenario-tree models to estimate the cost and sensitivity of the three regulatory French protocols of bTB surveillance in farms (Poirier et al., 2019): "strict", "compliant quick-path", and "compliant slow-path" protocols. These protocols all begin with the screening of cattle using the intradermal comparative cervical tuberculin test (SICCT). If at least one non-negative result is obtained in a herd, authorities consider the farm to be suspect and different protocols can be applied to investigate the suspicion.

In the strict and compliant quick-path protocols, non-negative animals are culled and laboratory tests (PCR, histology, and bacteriology) performed. If one of these tests detects *Mycobacterium tuberculosis, M. bovis*, or *M. caprae*, the herd is officially considered infected. Otherwise, in the

compliant quick-path protocol, the farm recovers its official bTB-free status, whereas in the strict protocol, a second negative SICCT on remaining animals in the herd is needed to recover the bTB-free status.

In the compliant slow-path protocol, cattle that are non-negative by the first SICCT (SICCT1) are tested with the interferon gamma test (IFNγ). The result of this test determines the next step of the protocol. If a cow obtains a positive result to the IFNγ test, it is culled and laboratory tests are performed, as for the two other protocols; otherwise cattle that were non-negative by SICCT1 are re-tested with the SICCT (SICCT2) six weeks later.

Scenario trees used to model these protocols were developed at the level of the individual animal. They accounted for herd type (production type, herd size, and herd turnover), age of the animal (younger or older than 24 months, which is the age limit at which they are tested with the SICCT), bTB status of the herd and that of the considered animal, and SICCT, IFNγ, and laboratory (PCR, histology and bacteriology) test results. Their implementation has been described in the corresponding published article (Poirier et al., 2019).

Here, we used these scenario trees as a starting point and integrated data concerning the veterinarians' practices into them.

2. Method for integrating data about actor practices into scenario trees

2.1. A qualitative survey to identify potentially influential factors on veterinarians' practices

The first step is to qualitatively investigate the participants' practices and the sociological context. Such a qualitative investigation has several aims. First, it allows better knowledge of existing differences in practices to be estimated quantitatively afterwards. Second, it helps to identify factors that potentially influence such practices. This leads to hypotheses that guide the quantitative investigation by indicating the factors for which data must be collected and to help formulate

appropriate questions and pertinent suggested answers. Finally, it provides a better understanding of the sociological context in which these practices are performed and of the actors' difficulties and concerns and thus highlights important information for the global discussion of the quantitative results and the suggestion of improvements. This survey should be performed through semi-directive interviews with the participants. The participants are chosen to maximally represent the diversity of field practices and contexts. The aim is not to be representative of the population of all actors of interest but to have a vision of all possible situations. In theory, the only rule deciding the size of the sample is "theoretical saturation": interviews stop when the interviewed actors express no more new ideas (relative to the previous interviews).

For example, no study has yet been conducted in France concerning the factors that influence the practice of the intradermal cervical tuberculin skin test (SICT) by veterinarians and/or their perception of the bTB surveillance and control program. Hence, a qualitative study was first conducted in collaboration with the French Ministry of Agriculture. Fifty-eight veterinarians with a rural activity from seven administrative areas were interviewed (semi-directive interviews) (Guillon et al., 2018; Gully and Hamelin, 2018). The seven administrative areas were selected to represent the diversity of French cattle farming concerning three factors. First, bTB infection levels (bTB prevalence between 2012 and 2016 and the existence of outbreaks after 2015) which could influence veterinary practices due to its potential influence on their perception of the prevalence of bTB and the number of SICCTs performed by each veterinarian (because the level of bTB infection influences the frequency of periodic screening of an area). Second, the main type of production (beef or dairy), which could influence cattle restraint facilities and therefore the difficulty to perform SICCTs. Third, the screening frequency (annual, variable -some parts of the area are annually screened and others less often or not all-, or every two, three, or four years), which influences the veterinarians' experience of practicing SICCTs, as it determines the number of SICCTs performed. During these semi-directive interviews, veterinarians were asked about the organisation of the periodic screening for bTB in their clinic, how they perform SICCTs in the field and what difficulties they encounter, how

150 they interact with the other actors of the surveillance program (farmers, authorities, cattle), and
151 their views concerning the bTB surveillance and control program, its necessity, and difficulties. Data
152 concerning their training, veterinary career, and demographic characteristics were also collected
153 (appendix A).

154 The results of this qualitative study (presented in the "results" section) guided the design of the
155 quantitative survey about the practices of veterinarians concerning SICCT and the collection of data
156 about the factors that potentially influent these practices. In addition, qualitative data concerning
157 the veterinarians' perception of the bTB surveillance and control program helped in the formulation
158 of the questions and suggested answers.

159 ### 2.2. A survey to quantify practices and the variables that potentially influence them

160 The objective of this survey is to quantify the occurrence of each type of practice and the factors
161 identified to potentially influence them. In our study, it was carried out by Crozet *et al.* (Crozet et al.,
162 2019). They performed an online survey and asked veterinarians about their practices of SICT,
163 notification habits, perception of the bTB surveillance and control program, and the characteristics of
164 their customer's farm (size, production type, restraining equipment, etc.). Data about the age, sex,
165 training, number of SICCTs performed in the previous year, and the percentage of rural activity of the
166 responding veterinarian were also collected. For the needs of our study, we only used the answers of
167 veterinarians who performed at least one SICCT during 2017 in the context of programmed farm
168 screening (115 of the 210 exploitable answers). Some of the raw results of the quantitative survey
169 needed to be transformed into more manageable variables.

170 ### 2.3. From the raw quantitative results to usable quantitative variables

171 #### 2.3.1.The SICCT practice index

172 The quantitative online survey contained questions to investigate each step of SICCT practices, in the
173 form of multiple choice questions in which the possible answers were determined according to the
174 deviance of SICCT practices from the regulatory protocol reported in the qualitative study for each

175 step of the test. For each of the eight steps **(Table 1)**, zero points were attributed to veterinarians if
176 they followed the regulatory protocol or if their practice of the test was considered to be
177 "acceptable", *i.e.* if the differences from the regulatory protocol were thought to have little impact
178 on the sensitivity of the SICCT and therefore tolerated by the health authorities. One point was
179 attributed if the veterinarian's practice of the test could negatively influence test sensitivity. For
180 example, for the injection site, zero points were attributed if they performed the injection on the
181 neck for all animals or for all calm animals. One point was attributed if they did not inject anything or
182 if they injected at other sites (which decreases the sensitivity of an SICT performed with the bovine
183 PPD antigen dose used in France (25,000 UI/ml) (Casal et al., 2015)).

184 Humblet *et al.* (Humblet et al., 2011) estimated the relative proportion of each step in influencing the
185 risk of obtaining a false negative result with a panel of bTB experts. Indeed, each step of the SICCT
186 has a specific influence on the characteristics of the SICCT (sensitivity, specificity). We thus attributed
187 a weight for each evaluated step based on their results. The attributed weights are presented in
188 **Table 1**. The final index for a veterinarian was the weighted sum of the points obtained for each step
189 and ranged from zero to eleven: the higher the index, the more the practice of the SICCT deviated
190 from the regulatory protocol.

191 2.3.2.The perception index

192 We used the same perception index as Crozet *et al.* (Crozet *et al.*, 2019) to represent the global
193 perception of the bTB surveillance and control program by the veterinarians. This index was
194 calculated from the answers of veterinarians to four themes: their major concern when they obtain a
195 non-negative result to an SICCT, their perception of the SICCT, the difficulties that prevent the
196 eradication of bTB, and their perception of the bTB surveillance and control program. The possible
197 answers to these questions were determined from analysis of the qualitative survey results. The
198 answers and corresponding attributed scores are presented in **Table 2.** For each answer, zero points

199 were attributed if it reflected a positive perception and one point for a negative perception of the
200 bTB surveillance and control program.
201 The final index was calculated by summing the points for each theme divided by the maximum
202 possible sum. We thus obtained an index between zero and one: The higher the perception index,
203 the worse the veterinarian's perception of the bTB surveillance and control program.

204 2.3.3.The notification index

205 The habit of veterinarians concerning the notification of non-negative results was evaluated using a
206 corresponding question in the quantitative survey. Zero points were attributed if they answered that
207 they did not systematically notify the authorities of all non-negative results obtained for the SICCT
208 and one point if they always did it.

209 2.4. The determination of major influential variables

210 Once the indexes described above were created, linear and/or logistic regressions (depending on the
211 type of the variable) of the results from the quantitative survey were performed to identify variables
212 that significantly influence the practice of interest (in our example, the SICCT practice index and the
213 notification index). For each variable, simple linear regression models were first used to select
214 predictor variables to include in a multivariable model (variable with p value ≤ 0.25). The selected
215 variables were then used in a primary multivariable model. The estimate of variance inflation factor
216 (VIF) for each predictor variable of this model allowed us to identify collinear variables. The
217 collinearity of two variables was investigated and their eventual removal (of one) was considered for
218 variables with a VIF > 3. Then, a Bayesian information criterion (BIC) based stepwise selection
219 procedure was used to simplify and optimise the multivariable model (R function "stepAIC" from the
220 MASS package (Venables and Ripley, 2002)). We added to the scenario trees only variables with a
221 significant impact on the practices of interest and which selection into the multivariable model had
222 the less probability to be due to chance, to retain high selectivity and avoid over complicating them,
223 we thus used a threshold of 0.01 for the p-value. The conditions of application of the model used

224 (linear or logistic regression) were verified. In our example, all linear regression models built for this
225 study had residuals with a normal distribution. The homoscedasticity of the residuals were
226 graphically checked. In addition, all logistic regressions had at least five to ten events by explicative
227 variables and ROC analysis was performed to evaluate their classification ability that seemed
228 satisfying. We thus considered the models to be valid.

229 2.5. Integrating factors that influence practices in the scenario trees

230 First, to account for the practice of a test, its influence on the sensitivity and specificity of the test
231 must be modelled. We modelled the link between the SICCT practice index and characteristics
232 (sensitivity and specificity) of the SICCT. The SICCT practice index accounted for the influence of each
233 step of the SICCT on the probability of obtaining false negative results, *i.e*. on sensitivity (paragraph
234 2.3.1). A null SICCT practice index means that veterinarians follow the recommended procedures of
235 the SICCT or that their practices are acceptable. In the literature on estimations of the characteristics
236 of the SICCT, in particular for French estimates, sensitivity and specificity are based on the results of
237 protocols monitored by the authorities, for which the veterinarian was committed to following the
238 rules for performing the SICCT. We hypothesised that their practices concerning the SICCT were at
239 least acceptable. In our scenarios trees, we therefore attributed sensitivity and specificity values
240 published in the literature to a null SICCT practice index. If the index is maximal (equal to 11), all
241 SICCT steps are inconsistent with regulatory prescriptions: we therefore hypothesised that in this
242 case, SICCT sensitivity is null and, consequently, SICCT specificity is perfect. Between these two
243 extremes, there was a large range of possible combination of practices for each step, each
244 combination having a potentially different effect on the SICCT characteristics. The true impact of
245 each of these combinations of practices is unknown and experts consider themselves incapable of
246 precisely estimating it (Humblet et al., 2011; experts of the French working group on bovine
247 tuberculosis). We therefore modelled this impact in our scenario trees by splitting the range of SICCT
248 practices index values into three equally sized categories to distinguish low SICCT index values from

249 average and high ones. We then assumed there to be decreasing sensitivity and increasing specificity
250 of the SICCT as we pass from one category (with the lowest value) to the next, *i.e.* if practices are less
251 acceptable, as described **in Table 3.**

252 If the practice of interest concerns case notification, a node, "notification", with at least two
253 branches ("yes", "no") must be added to the tree. The probability of occurrence of each branch will
254 be modelled according to the results of the quantitative survey. It is possible to include other types
255 of practices. The way to model their influence on the effectiveness of the surveillance system should
256 then be individually developed according to the context.

257 Then, nodes corresponding to the factors for which a significant influence on practices was identified
258 in the previous step of the method must be added to the scenario tree. The probability of occurrence
259 of each new branch generated by this addition of a node will be modelled according to the results
260 obtained in the quantitative survey by either a fixed probability (if there is no incertitude and no
261 variation in the probability of occurrence) or an appropriate distribution law (for example, Normal
262 distribution laws to model uncertainty and variability and parameters were chosen according to the
263 results of the multivariable analyses).

264 2.6. Simulations with scenario trees

265 Finally, the developed scenario trees were used to estimate the mean herd sensitivity (probability of
266 detection of at least one infected animal in an infected herd) and cost of each studied protocol and
267 their 95% confidence interval (CI) for a one-year period (bTB is a chronic disease and screening in
268 farms occurs every year) from 10,000 simulated values for each herd type. The scenario trees were
269 implemented in R (version 3.4.2).

270 First, the model calculated the probability of occurrence of each path by multiplying the probabilities
271 of occurrence of the corresponding limb. Then, it estimated the individual sensitivity for each type of
272 herd (Se_k) by adding the probability of occurrence of every path beginning with the nodes
273 corresponding to the herd type k (k corresponds to one of 12 possible categories of herd defined by

production type, herd size, and herd turnover) with a positive outcome. The initial hypothesis used in the creation of the scenario trees was that the specificity of the combination of analyses performed by the national reference laboratory for bTB was 100% (Poirier et al., 2019). Thus, individual specificity was equal to one in the scenario trees used. Finally, the sensitivity for each herd type (CSe_k) was calculated according to formula (1).

(1) $CSe_k=1-(1-Se_k)^{\text{herd size*intra-herd prevalence}}$

The estimated herd sensitivities by herd type were then compared to the estimated herd sensitivities without accounting for the veterinarian's practices of our previous study (Poirier *et al.*, 2019), modelled from the scenario tree presented in figures 1 to 3, without the nodes "Help for cattle restraint", "veterinarian's age", "perception index" and "Notification", corresponding to the node added to account for the veterinarians' practices.

3. Analyses of the results of the evaluation of bTB surveillance system on French farms

All analyses were performed using R (version 3.4.2). The accepted α risk of error was set to 1%. The means were compared using Student's t test, corrected for multiple comparisons by the Bonferroni correction method.

We evaluated which model input most influenced outcome uncertainty and variability by performing a sensitivity analysis for each scenario tree. As some inputs were interdependent, we could not use the AOT method and instead used the McKay method (McKay, 1995), which can be used for dependant inputs (Jacques *et al.*, 2006), with 20 replications of Latin hypercube samples. We used the R package "sensitivity dependent" (Jacques, 2014).

RESULTS

297 1. Results of the qualitative survey on veterinarians' SICCT practices and their perception of the bTB
298 surveillance and control program

299 The qualitative study showed that regulatory protocols for the practice of SICCT were not
300 systematically followed in ways that may highly influence test sensitivity and specificity. It also
301 showed that veterinarians do not always notify the authorities of non-negative results. This
302 confirmed the interest of assessing veterinarians' practices in our quantitative evaluation of the bTB
303 surveillance component in cattle. This study provided veterinarians the opportunity to freely express
304 their difficulties in performing bTB surveillance in the field, allowing us to formulate hypotheses
305 concerning the factors that influence their practices in bTB surveillance. The constraints and
306 motivations for SICCT screening expressed by veterinarians varied, depending on herd type,
307 screening frequency, and prevalence of bTB. For example, SICCT practices appeared to better
308 conform to regulatory protocols in administrative areas with a higher prevalence of bTB, perhaps
309 because veterinarians are well informed about these protocols and have more training in their
310 application. Veterinarians justified their adaptations of regulatory SICCT protocols because of the
311 difficulty of restraining cattle associated with the danger of performing the SICCT along with its time-
312 consuming nature. They justified the non-notification of some non-negative results to the authorities
313 because of their lack of confidence in the results. Indeed, the prevalence of bTB in France is very low
314 and non-negative results are therefore often false-positive results due to the lack of specificity of the
315 test. In addition, the economic consequences of the notification of such results are substantial for
316 the farmer, as their herd becomes suspect of carrying bTB and they can no longer sell any animals
317 during all the investigation process, which can be very long (more than six weeks when the herd must
318 be screened a second time with the SICCT). Some veterinarians therefore hesitate to notify the
319 authorities of a non-negative result because they do not trust a positive result of the SICCT and do
320 not want to negatively (and sometimes unjustifiably) affect the farmer, who is also their customer.
321 Veterinarians appeared to have a different perception of the bTB surveillance system depending on
322 the prevalence bTB in the area and screening frequency. Indeed, the perception of veterinarians

323 appeared to be better in areas more highly affected by bTB (higher bTB prevalence, higher frequency
324 of screening), *i.e.* they seemed to be more convinced of the importance and utility of the bTB control
325 program.

326 The results of this first qualitative study allowed us to identify the factors that potentially influence
327 the practice of the SICCT and notification of non-negative SICCT results: prevalence of bTB in the
328 area, screening frequency, herd type, restraining devices, trust in the SICCT results, and
329 veterinarians' perception of the bTB surveillance system.

330

331 2. Factors that influence the practice of SICCT from the quantitative survey results

332 First, we sought explicative variables for the SICCT practice index based on the analysis of the
333 quantitative survey results carried out by Crozet *et al.* (Crozet et al., 2019). Results of the simple
334 linear regression are shown in Appendix B. Variables representing the help in restraining cattle and
335 the screening rhythm in the area in which the veterinarian works were forced into the primary
336 multivariable model because they appeared to influence the practice of the SICCT, according to the
337 preliminary qualitative study. All VIFs were ≤ 2 and we found no collinear variables that could
338 introduce a bias in the estimation of the model parameters. Results of the final model obtained after
339 the automatic selection process are shown in **Table 4**. The only variable significantly associated ($p <$
340 0.01) with the SICCT practice index was the perception index: veterinarians with a better perception
341 of the bTB surveillance and control program had a better SICCT practice index. We therefore fitted a
342 model explaining the SICCT practice index with the perception index, which is presented in **Table 5**.

343 Having determined that the perception index was the only variable significantly associated with the
344 SICCT practice index, we wanted to determine which variables could influence the perception index.
345 We used the same method as for the SICCT practice index: the results of the simple linear regressions
346 are summarized in appendix C and those of the final multivariable regression in **Table 6**. The age of
347 the veterinarian, the number of people from the farm usually present to help for animal restraint

348 during screening, and the frequency of headlocks were the only variables significantly associated
349 with the perception index. Veterinarians over 50 years of age tended to have a more positive
350 perception of bTB control, probably because they were already practicing before France obtained its
351 bTB-free status, when the prevalence of bTB was much higher, and they therefore have a better
352 awareness of the importance of bTB surveillance and control. Veterinarians who usually received
353 appropriate help for animal restraint (at least two people of the farm) when carrying out the SICCT
354 and veterinarians working in farms in which headlocks were frequent had a more positive perception
355 of the bTB surveillance and control program, probably because it is easier for them to perform the
356 SICCT. A regression model explaining the perception index by these three major variables was fitted
357 (Appendix D).

358 We carried out similar analyses to explain the number of people usually helping in animal restraint
359 (by logistic regressions) and the frequency of headlocks. Results of these analyses are presented in
360 appendices E, F and G. None of the variables were significantly associated neither with the number of
361 people usually present to help the veterinarian during his visits nor with the frequency of headlocks.

362 Finally, we determined which variables were significantly associated with notification practices using
363 the same method. Results of the multivariable analysis are shown in **Table 7**. The perception index
364 was the only variable associated with the notification of non-negative results with a p-value close to
365 0.01 (p-value=0.03) and had an important influence on this variable in the logistic regression (high
366 estimated coefficient). In addition, a real influence of veterinarian's perception of bTB on the
367 notification of non-negative results seemed logical and was consistent with the qualitative study
368 findings. Therefore, we chose to account for it in our scenario tree modelling.

369

370 3. Awareness of veterinarians' practices in the scenario trees modelling bTB surveillance in farms

371 We next added nodes corresponding to variables with a significant influence to the scenario trees
372 identified by the previous multivariable analyses. We thus added the nodes "help in cattle restraint"

373 (less than two people or at least two people), “veterinarian’s age” (under or over 50 years),
374 “headlocks frequency” (prevalent or less prevalent) and “notification of non-negative SICCT results”
375 (yes or no). The final scenario trees obtained for each protocol are shown in **Figures 1 to 3**.

376 The probability of occurrence of each of the new limbs was modelled by beta distribution laws. The
377 probability of the veterinarian to receive help in restraining the cattle from at least two people from
378 the farm was modelled by a beta distribution law with parameters set to best fit the real distribution
379 observed in the quantitative results of the survey: $\beta(49, 64.9)$. The probability of the veterinarian
380 being under or over 50 years old was set according to the French national data from the
381 demographic atlas of veterinarians from 2018 from the National Observatory demographics of the
382 veterinary profession. Veterinarians thus had a fixed probability of 33% of being over 50 years old.

383 The age of the veterinarian, number of people usually present to help for cattle handling in a herd
384 and the frequency of headlocks have an influence on the value of the perception index to be used in
385 the scenario trees. Indeed, in the models, a perception index was simulated for each iteration using a
386 beta distribution law. The parameters of these distributions were set, depending on the limb,
387 according to the results of the survey, as described in **Table 8**.

388 Finally, for each iteration of the model, the value of the perception index shaped the SICCT practice
389 index, which influences the sensitivity and specificity of the SICCT and the probability of the
390 veterinarian notifying the authorities of a non-negative SICCT result.

391 As the results of the multivariable model explaining the SICCT practice index showed that the
392 perception index was the only variable that significantly influenced the practice of the SICCT, we
393 modelled the SICCT practice index according to the perception index, using the results of the
394 multivariable model. In the scenario trees, the SICCT practice index was therefore calculated
395 according to formula (2).

396 (2) $\text{SICCT practice index} = c * \text{perception index} + \varepsilon$

397 Where c followed a normal distribution law N(mean = 4.37, sd = 1.20), for which the parameters
398 were set according to the result of the multivariable analysis explaining the SICCT practice index
399 (**Table 5**); and ε, the residue of the multivariable regression, followed a normal distribution law
400 N(mean = 1.80, sd = 0.39) and was included between - c*perception index and 11- c*perception
401 index.

402 The probability of the authorities being notified of a non-negative result was modelled by beta
403 distribution laws with parameters set according to the quantitative survey and is shown in **Table 9**.

404 For protocols with a second SICCT (strict protocol and compliant slow-path protocol), we
405 hypothesized that the veterinarians would systematically notify the authorities of non-negative
406 results of the second SICCT because they performed these test in a suspected herd attentively
407 monitored by the authorities and for which misidentification of a suspect animal could have
408 important consequences.

409

410 4. Results of the evaluation of bTB surveillance by screening of French farms

411 4.1. Herd sensitivity

412 **Table 10** summarizes the mean and 5th and 95th percentiles of the output distribution for the herd
413 sensitivity for each protocol by herd type. Mean herd sensitivity ranged from 12.7% for the compliant
414 quick-path protocol (in big beef-cattle farms with a high turnover) to 46.2% for the strict protocol (in
415 big mixed farms with a low turnover).

416 4.2. Impact of the incorporation of data on SICCT and notification practices

417 Integrating data on SICCT and non-negative result notification practices resulted in a major decrease
418 (the value of the percentage of decrease was between 15% and 42% depending on herd type) of the
419 initial herd sensitivity estimations without practices data, regardless of herd type and protocol (**Table**
420 **11**). For a given protocol, the decrease in the estimated herd sensitivity was significantly lower for big

421 herds than small herds (of the same production type and herd turnover) and for big mixed herds
422 than other big herds. For a given herd type, the difference in the decrease of the estimated herd
423 sensitivity was not significant between the compliant slow-path and compliant quick-path protocols,
424 whereas it was significantly smaller for the strict protocol than the compliant slow-path and
425 compliant quick-path protocols.

426 4.3. Sensitivity analyses

427 Mc Klay indices of inputs > 10% by herd type for each protocol are shown in **Figure 4**. This index
428 estimates the proportion of variation of the output caused by the variability and uncertainty of the
429 inputs. SICCT sensitivity had the greatest influence on variations of herd sensitivity for small herds
430 and big dairy herds, for the compliant slow-path protocol. In other big herds and for the two other
431 protocols, SICCT sensitivity, within-herd prevalence, and herd size significantly influenced this
432 variation.

433

434 DISCUSSION

435 1. Method

436 The method we developed has the advantage of combining data from diverse sources, including
437 qualitative field data collected using a sociological methodology among actors and quantitative data
438 with variability and uncertainty. The main setback of this approach is the large amount of time and
439 human and financial resources needed to perform it.

440 The method of semi-directive interviews also requires knowledge and skills in sociology. This
441 interdisciplinarity is highly rewarding but brings the risk of misusing the method if it is insufficiently
442 mastered. A collaboration with sociologists could therefore be very useful, as they would ensure the
443 quality of the qualitative study and would provide a better understanding of the field in a sociological

444 context. The results of this qualitative study should not be set aside once the quantitative survey is
445 launched as they would be a rich source of information, possibly leading to field recommendations.

446 For this qualitative study, we interviewed veterinarians from chosen administrative areas. However,
447 each area has a unique distribution of the type of cattle production and its own sanitary authority
448 unit, in which the interactions between actors vary. We therefore may have overlooked certain
449 issues specific to the context of a particular area. Nevertheless, the aim of this study was to globally
450 evaluate the impact of veterinarians' SICCT practices on the effectiveness of surveillance and the
451 selected areas were representative of the diversity of French areas for global context indicators (type
452 of production, prevalence of bTB and context, and periodic screening frequency). Thus, it likely
453 allowed us to obtain a good picture of the predominant practices and influential factors at the
454 national level.

455 All semi-directive interviews can lead to biases caused by the interviewer/interviewee interaction, as
456 they each have their own socio-economic background, which may affect their relationship and thus
457 the interviewee's discourse. Although such bias cannot be completely avoided, it can be minimised
458 by the attitude of the interviewer. In our case, he could potentially have been perceived as an
459 "officer" who could report irregular practices to authorities, as the interview concerned regulatory
460 practices. Nevertheless, the careful presentation of the interviewer and objectives of the study
461 appears to have limited such bias, as many of the interviewees reported practices differing from
462 regulatory guidelines.

463 Any bias in our quantitative survey is well described by Crozet *et al.* (Crozet et al., 2019).
464 Veterinarians of our sample had demographic characteristics similar to the ones of Crozet et al.'s
465 study; selecting a subset of their sample did not seem to have introduced additional selection bias.
466 Concerning the perception index, it may be presumptuous to believe that this index truly measures
467 the veterinarians' perception. Indeed, "veterinarians' perception" is more a sociological concept than
468 a physical variable (unlike the SICCT practice index, for example). In sociology, quantifying a concept

469 through several measurable variables is normal but requires the development of a measurement tool
470 according to the paradigm of Churchill (Churchill, 1979), summarised in Appendix H. Our approach of
471 perception measurement was less subtle and could be improved by following this paradigm to
472 ensure that it is reliable and "measures what it is supposed to measure" (Bollen, 1989). This could be
473 a full research project in itself, more suited to a sociologist, what underlines the interest of a
474 multidisciplinary collaboration.

475 Our modelling of the impact of SICCT practices on the SICCT characteristics is very simplified, partly
476 as there was no detailed data on it and also because the scenario trees, being themselves
477 simplifications of reality, would not have accounted for all the diversity of possible practice
478 combinations. This simplification may have led us to amplify the negative effects of adapted SICCT
479 practices and thus to underestimate the herd sensitivity of the protocols. Indeed, a veterinarian
480 could, for example, be assigned an SICCT index of one, leading to a 25% decrease of the SICCT
481 sensitivity in the model, because the person reading the test result is occasionally another
482 veterinarian; thus, we would systematically consider that the test sensitivity is 25% lower, whereas
483 the veterinarian sometimes reads the test result himself or herself. In addition, the percentage of the
484 decrease in sensitivity is purely theoretical and may have been over-estimated. Nevertheless, the
485 direction of the influence on the SICCT characteristics we modelled is logical. It therefore seems
486 legitimate to consider that the direction of the estimated influence of sociological data on herd
487 sensitivity reflects the true direction of this influence. However, the limitation caused by this
488 simplification must be kept in mind when considering the quantitative estimation of the influence of
489 practices on herd sensitivity. We estimated that with a linear impact decreased of 50%, SICCT
490 practices impact on protocols' sensitivity will still be significant, causing a decrease of protocols
491 sensitivity of 16% to 21% compared to sensitivities estimated without accounting for veterinarian's
492 practices. Further investigations are necessary to verify our assumption to collect additional data
493 about veterinarians' practices, the results of the tests they performed and the infection status of the
494 corresponding animals estimated through laboratory analysis. Unfortunately, French centralised data

495 of the results of SICCT and of suspicions' investigations are not yet sufficiently detailed and collecting
496 them at a local scale will be very time-consuming.

497 The general trend of the influence of altered SICCT practices on the test characteristics was easy to
498 evaluate using existing published studies (Doherty et al., 1995; Humblet et al., 2011; Benet et al.,
499 2012; Casal et al., 2015). This modelling may be less obvious to perform for the tests used in other
500 disease surveillance systems.

501

502 2. Results

503 Some potentially influential factors identified in the qualitative study, such as the relationship
504 between veterinarians and sanitary authorities and between veterinarians and farmers, were difficult
505 to assess quantitatively and were therefore not directly accounted for in our scenario trees. These
506 factors should nevertheless not be underestimated and all actions improving these relationships
507 should be enhanced.

508 In the quantitative study results, there were no differences in practices between French
509 administrative areas. We assumed that there is some heterogeneity between these areas (this was a
510 hypothesis based on the qualitative survey), in particular depending on the bTB prevalence and the
511 historical context. The quantitative survey may have not confirmed this hypothesis because of a lack
512 of statistical power due to the limited number of responding veterinarians (115/1,084). Thus, the
513 input parameters were set according to aggregated data from all of the targeted areas. We thus
514 obtained an effectiveness estimation of the protocols in the global sociological context of the
515 investigated areas. However, the practice of SICCT in certain French areas, where veterinarians were
516 particularly well trained for SICCT and well informed about bTB, is known to be better than others,
517 closer to recommendations (personal communication from the French national referent of bTB
518 surveillance Fabrice Chevalier). It appears to be validated by the decreasing prevalence of bTB in
519 these areas (Direction Générale de l'Alimentation, 2010). We can therefore expect herd sensitivity of

520 the protocols in these areas to be higher than our estimations and closer to the first estimation we
521 made (Poirier et al., 2019).

522 The creation of an index to represent SICCT practices was necessary to allow analysis of the results
523 but it simplified the true complexity of practicing SICCT in the field. Indeed, altered practices at each
524 step of performing the test led to an increase in the SICCT practice index. However, some steps are
525 more essential than others and some practice adaptations may not lead to a decrease in SICCT
526 sensitivity. We tried to account for this complexity by attributing a weight to each step of the test,
527 accounting for their varying impact on the probability of obtaining false negative results, and
528 "tolerating" certain adapted practices that probably have no consequences on the SICCT
529 characteristics. Nevertheless, it is still an imperfect simplification and therefore, a high SICCT practice
530 index is not the exact equivalent of reduced test effectiveness in the field.

531 In the analysis of their results, Crozet *et al.* (2019) found the same influence of the veterinarians'
532 perception of bTB surveillance and control on the SICCT practice index. However, they found two
533 variables which were more influential (with a smaller effect than the veterinarians' perception): the
534 number of years in large animal practice and the number of performed SICCTs during the last year.
535 The influence of these two variables was not significant in our analyses. This is not surprising given
536 that we only analysed the responses of veterinarians that practice SICCT in a periodic screening
537 context (veterinarians practicing SICCT only on cattle to sell or to investigate epidemiological links
538 with outbreak were excluded) as they were the only ones pertinent to our scenario-tree modelling.
539 We therefore had less data (115 answers instead of 210), probably resulting in a lack of power.

540 Veterinarians with a better perception of the bTB surveillance and control program had a better
541 SICCT practice index. This is probably explained by a better understanding of the importance of bTB
542 control: veterinarians convinced that controlling bTB is useful and necessary will certainly more
543 carefully follow regulatory recommendations, despite the constraints, than veterinarians thinking it is
544 useless (Brennan et al., 2016).

545 We assumed that veterinarians notified all non-negative results for a second SICCT (SICCT2) because
546 SICCT2 are performed in suspect herds monitored by authorities and in which veterinarians have
547 notified of non-negative results to the first SICCT. It is thus likely that they will notify of it for SICCT2.
548 However, this hypothesis may have been optimistic and may have slightly overestimated the number
549 of notifications and therefore herd sensitivity. On the other hand, we accounted for the impact of
550 SICCT practices on the SICCT2 characteristics. Yet, it is possible that some veterinarians that did not
551 follow the regulations for SICCT1 will follow regulatory practices for SICCT2, given the context: in this
552 case, we may have slightly underestimated herd sensitivity of strict and compliant slow-path
553 protocols.

554 Veterinarians that declared that they did not systematically report non-negative results were
555 considered in the model as if they never notified authorities of any non-negative SICCT1 results. This
556 lacks nuance as the qualitative survey showed that some of them do their own personal risk analysis
557 to decide whether to notify the authorities or not. Such behaviour is indeed detrimental for the
558 effectiveness of the protocol, but it is not as detrimental as systematic non-notification. Therefore,
559 we certainly overestimated non-declaration and thus slightly underestimated true herd sensitivity.
560 Nevertheless, such behaviour is inconsistent with the effective control of bTB, that is why we chose
561 to account for these veterinarians as if they never notified the authorities of any SICCT non-negative
562 results. In addition, this type of approach, based on declarations concerning regulatory practices,
563 could have led to some veterinarians under-declaring altered practices.

564 The herd sensitivity estimations based on scenario trees were therefore imprecise but allowed us to
565 show the important influence of the practice parameters of the actors on herd sensitivity for the
566 different protocols. It highlights the importance of optimising SICCT practices and the notification of
567 non-negative results of bTB surveillance and underlines the importance of accounting for data
568 concerning these practices in surveillance system evaluations. Interestingly, the adaptations of
569 practices made by veterinarians, certainly to decrease the cost to farmers, probably has the desired

570 impact on protocol cost, with the unfortunate collateral damage of decreasing herd sensitivity. Such
571 adaptations of practices decrease the effectiveness of the protocols and negatively affect the long-
572 term cost of the surveillance program, as it slows down and perhaps prevents the eradication of bTB.
573 According to the qualitative survey, these adaptations are a reaction to the restrictive regulations of
574 the European Union, which prescribes a selling ban for all suspect herds (for example fort at least six
575 weeks in the strict protocol). In addition, in the context of very low prevalence and given the
576 characteristics of the SICT, the confidence veterinarians have in a non-negative SICCT is low.
577 Combining these two considerations, some veterinarians perform their own risk analysis and may
578 decide, for example, to overlook certain non-negative results. It is probable that these adaptations of
579 practices may differ, depending on the bTB history in the area, its prevalence, and the production
580 type of the herd (because a selling ban could have greater economic consequences for a beef herd
581 than a dairy herd). Such adaptations of practices can probably be found in other European countries
582 subject to the same regulations with similar historical and epidemiological contexts.

583 Our herd sensitivity estimations suggest that periodic screening using the SICCT may not be very
584 effective for the detection of infected herds. However, our herd sensitivity estimations only reflect
585 the effectiveness of a single screening campaign, whereas such campaigns are regularly performed in
586 France (up to one every year), which improves the probability of eventually detecting an infected
587 herd. In addition, periodic screening is not the only surveillance system in place in France and its
588 association with the screening of transported cattle, slaughterhouse surveillance, and the
589 investigation of farms linked to outbreaks guarantees more effective detection of infected herds.

590 According to the sensitivity analyses, SICCT sensitivity and within-herd prevalence were the main
591 influential variables. This is not surprising, given the uncertainty we had concerning their values and
592 major role in disease detection. Inputs concerning practices were not the most influential variable on
593 outcome variability but they contributed approximately 1% to 10% to it, depending on the herd type

594 considered. Improving SICCT practices, the frequency of notification, and/or the perception of bTB
595 control could thus have a positive impact on herd sensitivity.

596 The percentage of the decrease of estimated herd sensitivity caused by incorporating SICCT and
597 notification practices of veterinarians was lower in the strict protocol (regardless of herd type), in big
598 herds (for a fixed production type and herd turnover, regardless of the protocol), and in mixed herds
599 (for a fixed herd size and herd turnover). For the strict protocol, this difference can be explained by
600 the fact that the test is used twice in parallel, which led to the smallest percentage decrease relative
601 to protocols in which the test is used only once or serially (Appendix I). For big and mixed herds, it
602 was due to the higher number of infected animals tested (Appendix I). Indeed, as there is a large
603 number of animals in such herds with a same within-herd prevalence, in the model, large and mixed
604 infected herds will have a higher number of infected animals that will be tested, leading to higher
605 herd sensitivity, which may compensate for the decrease in herd sensitivity due to altered practices.
606 This difference decreases with a decrease of the modelled impact of SICCT practice on SICCT
607 characteristics. In addition, the high number of iterations used lead to narrow confidence intervals
608 but with less iterations, many of the differences between herd types are not significant.

609

610 3. Field recommendations

611 According to our study, improving veterinarians' perception of the bTB surveillance and control
612 program could enhance the effectiveness of the surveillance system by improving their SICCT
613 practices. This is consistent with several qualitative studies (Pfeiffer, 2006; Brennan et al., 2016). This
614 could be achieved by addressing cattle-handling issues, which could be dealt with through (1)
615 technical and financial help for farmers towards adapted handling devices, such as head-lockers
616 (Crozet et al., 2019) and (2) training for farmers to make them aware of the need of having several
617 people to help in restraining the cattle. The veterinarians' perception of the bTB surveillance and
618 control program can also be improved by training to convince them of the utility of control and

619 reassure them of its feasibility. It is likely that the training needs in France will be heterogeneous,
620 depending, for example, on the bTB prevalence in the area (Crozet *et al.* 2019).

621 Finally, an additional possibility to improve veterinarians' and farmers' perception of the bTB
622 surveillance and control program could be an improvement of the protocol. For example, the second
623 SICCT test could be replaced by an IFNγ test, leading to potentially better cost-effectiveness and a
624 shorter duration of the protocol, such as by decreasing the time between the first and second SICCT,
625 during which farmers cannot sell any animals. Such protocols could positively influence veterinarians'
626 perception and reduce their reluctance to declare non-negative results, leading to an improvement
627 of bTB surveillance on farms, as they would be less penalizing for the farmers. In addition, the IFNγ
628 test is easier to perform for the veterinarian, as only one blood sample is required, causing fewer
629 cattle-restraint issues, and interpretation of the result is performed in a laboratory. Nevertheless,
630 changing these protocols will require modification of the European regulatory protocols.

631

632 CONCLUSION

633 In this study, we developed a method to integrate practices data into scenario tree modelling and
634 used it to evaluate the impact of the SICCT practices on French bTB surveillance system. Further
635 studies have yet to be done to improve the modelling of the impact of SICCT practices on its
636 sensitivity and specificity. However, our study highlighted the importance of the veterinarians'
637 involvement and the need to convince them of the utility of controlling bTB and of the necessity to
638 perform the tests according to regulatory recommendations. Authorities could provide technical and
639 financial support to help them in practicing the SICCT, in particular for animal restraint and for an
640 awareness program of the utility of controlling bTB.

641

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740 APPENDICES

741 *Appendix A. Guide used for the semi-directive interviews of the qualitative study (translated from the work of Gully S. and*
742 *Hamelin E., 2018)*

743 **First part: characteristics of the veterinarian**

744 In a few words, describe your career

745 *Anticipated data: Education and training, age, sex, work experience, status in the clinic (employee or*
746 *private practitioner)*

Second part: organisation of bTB screening in the clinic

- What is the proportion of rural activities of the clinic?

Anticipated data: size of the structure, proportion of rural activity of the overall activity of the clinic, distribution of work between veterinarians of the clinic, position of the interviewee in the general organisation of the clinic. Competitive context of the clinic.

- Who performs bTB screenings in the clinic?

- For your rural activity, what is the context of the area you cover? What type of cattle are there and what type of interventions do you usually perform?

Anticipated data: economical context of the farmers, relationship with the farmers, type of herds (dairy vs *beef, type of cattle housing), size of herds*

747

Third part: training/experience

- How and when were you educated about bovine tuberculosis (bTB)? (Education about the characteristics of the bacteria and bTB issues, training to perform the intradermal cervical tuberculin test (SICT), education about the characteristics of the SICT)

- Do you perform SICT?
- What type of SICT (SSICT (single intradermal cervical tuberculin test) or SICCT (intradermal cervical comparative tuberculin test)) do you perform more often?
- What is your experience concerning bTB

Anticipated data: the veterinarian knew about bTB before the bTB-free status of France or he never worked in bTB infected areas. In which context does he perform SICT (screening, in herds with an epidemiological link to an outbreak, for purchased animals)? Frequently/rarely?

748

Fourth part: field practice

- How well does bTB screening go in the field? How do you proceed?

  Anticipated data: SSICT or SICCT, description of the procedure, preparation of the injection site, first measurement of skin thickness, how it is measured, injection quality check and reinjection if necessary, time of reading, type of reading (measurement of skin thickness?), difference between SSICT and SICCT.

- How do you manage the restraint of cattle?

  Anticipated data: differences depending on the herd, cattle type (race, age…)? Difficulties? Frequency of difficulties?

- What difficulties do you encounter?

  Anticipated data: cattle restraint, relationship with the farmer, relationship with health authorities, the SICT itself (training, management, etc.)

- What do you think about the fees for the SICT?

Anticipated data: How and how much are you paid for a SSICT? for an SICCT? What is the financial profitability of each one of these tests for the clinic?

- Have you ever detected cattle with a small reaction to SICT? with a big one?

  Anticipated data: collect information about their management of doubtful results and under-notification.

- Have you ever had a non-negative case? Could you tell me how it happened and what you did? Do you always manage a non-negative case the same way?

- Have you ever had to manage a complex case (use the veterinarian's lexical field)? Could you tell me how it went? What did you do? Do you always manage a non-negative case the same way?

  Anticipated data: succession of decisions and actions; if several cases, ask the veterinarian to talk about each one and ask whetherthere were differences in the reactions? If there were, why? Finish by a question summarizing: What did you learn from this experience? If you had to do it again, would you do some things differently? Why?

- Have your practices changed since your first participation in a bTB screening campaign? What did you change? Why?

- Has your management of complex cases changed since your first case? Why?

- How is it with the other veterinarians of the clinic: do you sometimes discuss bTB screening? About which facet in particular?

  Anticipated data: When you detected a non-negative result for an SICT, did you talk about it

in the clinic? If you did, what did you discuss? (We want to understand whether veterinarians share experiences and whether they try to standardize their practices within the clinic.

- How is it with the other stakeholders of the bTB control program?
  - With the farmers? Are they your usual customers? How does the collaboration work? How do you react to the refusal of a farmer?
  - With the animals? What do you do when it is difficult to restrain the animals? Potentially, if the veterinarian talks about certain types of cattle or a race in particular: Are there some animals for which you proceeded differently? Why?
  - With the health authorities of the area? How does information circulate? How available are the health authorities? Who is your representative? Have you participated in meetings with the local health authorities?
  - What is the role of the GDS[(1)] (health defence group, group of farmers)?
  - With the GTV (veterinary technician group)

749

Fifth part: veterinarian's perception of the bTB surveillance and control program

Finally, what do you think about the bTB surveillance and control program? What works and what doesn't? What are the main difficulties? What should be changed? Why do you think health authorities continue with the program? What do you foresee in the next 5 years?

750

751

752 *Appendix B. Results of simple linear regressions explaining the SICCT practice index (n = 115))*

Predictor variable	p-value	Comment on the predictor variable
Perception index	0.00043**	Continuous
Veterinarian's sex	0.525	Binary (Man/Woman)
Veterinarian's age	0.358	Categorical (≤ 30 years, 31-40, 41-50, 51-60, > 60)
	0.439[F]	Categorical (< 50 years, ≥ 50 years)
Number of years of rural practice (in years)	0.813	Continue
Veterinary school	0.03566*	Categorical (Abroad, Nantes[1], Toulouse[1], Lyon[1] , Alfort[1])
Veterinarian's status	0.50	Categorical (self-employed/employee)
Number of SICCTs performed in 2017	0.882	Continuous
Proportion of SSICTs among the SICTs performed by the veterinarian	0.0151*	Continuous
Proportion of rural practice	0.2827	Categorical (≤ 20%, 20-40, 40-60, 60-80, 80-100)
Prevalence of headlocks on the veterinarian's customer's farms	0.0494*	Categorical (prevalent (n = 40)/ less prevalent (n = 75))
Prevalence of restraining corridors on the veterinarian's customer's farms	0.011*	Categorical (prevalent (n = 62) / less prevalent (n = 53))
Help during cattle handling	0.379[F]	Categorical (< 2 people, ≥ 2 people)
Production type	0.107*	Categorical (dairy/beef/mixed)
Herd size	0.856	Continuous
Maximal screening rhythm in the areas where the veterinarian works	0.312 [F]	Categorical (annual, biennial or triennial, stopped or zoned)
prevalence of bTB in the areas where the veterinarian works	0.581	Categorical (bTB free or 1 to 5 breakouts more than 5 years ago, infected (1 to 10 breakouts in the last 5 years), highly infected (more

	than 10 breakouts in the last 5 years)

753 **significant with α = 0.01, included in the multivariable analysis

754 *non-significant, but p < 0.25, so included in the multivariable analysis

755 [F] Variables forced into the primary multivariable model

756 [1] The four French veterinary schools

757 SSICT: single intradermal tuberculin cervical test

758 SICCT: intradermal cervical comparative tuberculin test

759 SICT: intradermal cervical tuberculin test (it can be an SSICT or an SICCT)

760

761 *Appendix C. Results of simple linear regressions explaining the perception index*

Predictor variable	p-value	Comment on the predictor variable
SICCT index	0.00043**	Continuous
Veterinarian's sex	0.229*	Binary (Man/Woman)
Veterinarian's age	0.024*	Categorical (< 50 years, ≥ 50 years)
Number of years of rural practice (in years)	0.103*	Continuous
Training school	0.187*	Categorical (Abroad, Nantes[1], Toulouse[1], Lyon[1] , Alfort[1])
Veterinarian's status	0.329	Categorical (self-employed/employee)
Proportion of SSICTs among the SICTs performed by the veterinarian	0.12*	Continuous
Number of SICCTs performed in 2017	0.523	Continuous
Proportion of rural practice	0.078*	Categorical (≤20%, 20-40, 40-60, 60-80, 0-100)
Restraining help	0.00081**	Categorical (< 2 people, ≥ 2 people)
Prevalence of headlocks on the veterinarian's customer's farms	0.017*	Categorical (prevalent (n =4 0)/less prevalent (n = 75))
Prevalence of restraining corridors on the veterinarian's customer's farms	0.997	Categorical (prevalent (n =6 2)/less prevalent (n = 53))
Herd size	0.277	Continuous
Maximal screening rhythm in the areas were the veterinarian works	0.2029*	Categorical (annual, biennial or triennial, stopped or zoned)
Prevalence of bTB in the areas were the veterinarian works	0.522	Categorical (bTB free or 1 to 5 breakouts more than 5 years ago, infected (1 to 10 breakouts in the last 5 years), highly infected (more than 10 breakouts in the last 5 years)
Production type	0.1413*	Categorical (dairy/beef/mixed)

762 **significant with α = 0.01, included in the multivariable analysis

763 *non-significant but $p < 0.25$, so included in the multivariable analysis

764 [1] The four French veterinary schools

765 SSICT: single intradermal tuberculin cervical test

766 SICCT: intradermal cervical comparative tuberculin test

767 SICT: intradermal cervical tuberculin test (it can be an SSICT or an SICCT).

768

Appendix D. Results of the multivariate logistic regressions explaining the perception index with veterinarian's age, the number of people from the farm usually present to help for animal restraint during screening, and the frequency of headlocks

Adjusted R^2 = 0.1587
F statistic = 8.171
Model's p-value < 0.001
Residual standard error = 0.1105 (degrees of freedom =111)

	Estimated coefficient	**Standard error**	**p-value**	**Reference category**
Constant	0.38	0.019	$< 2.\ 10^{-16}$**	/
Veterinarian's age (< 50, ≥ 50)	-0.049	0.021	0.019*	< 50 years
Headlock frequency (prevalent/less prevalent)	-0.057	0.022	0.0098**	Less prevalent
Restraining help (<2 people / ≥2 people)	-0.069	0.021	0.0013**	< 2 people

**p ≤ 0.01, significant association
*p < 0.05

779 *Appendix E. Results of the simple logistic regressions explaining the restraining help variable*

Predictor variable	p-value	Comment on the predictor variable
Veterinarian's sex	0.169*	Binary (Man/Woman)
Veterinarian's age	0.4144 [F]	Categorical (< 50 years, ≥ 50 years)
Number of years of rural practice (in years)	0.851	Continuous
Veterinary school	0.274	Categorical (Abroad, Nantes[1], Toulouse[1], Lyon[1] , Alfort[1])
Veterinarian's status	0.812	Categorical (self-employed/employee)
Number of SICCTs performed in 2017	0.939	Continuous
Proportion of SSICTs among the SICTs performed by the veterinarian	0.0446*	Continuous
Proportion of rural practice	0.851	Categorical (≤ 20%, 0-40, 40-60, 60-80 , 80-100)
Prevalence of headlocks on the veterinarian's customer's farms	0.705	Categorical (prevalent (n = 40)/ less prevalent (n = 75))
Prevalence of restraining corridors on the veterinarian's customer's farms	0.0846*	Categorical (prevalent (n = 62) / less prevalent (n = 53))
Production type	0.9493	Categorical (dairy/beef/mixed)
Herd size	0.913	Continuous
Maximal screening rhythm in the areas were the veterinarian works	0.1232*	Categorical (annual, biennial or triennial, stopped or zoned)
Prevalence of bTB in the areas were the veterinarian works	0.0388*	Categorical (bTB free or 1 to 5 breakouts more than 5 years ago, infected (1 to 10 breakouts in the last 5 years), highly infected (more than 10 breakouts in the last 5 years)

780 **significant with α = 0.01, included in the multivariable analysis

781 *non-significant, but p < 0.25, so included in the multivariable analysis

782 [F] Variables forced into the primary multivariable model

783 SSICT: single intradermal tuberculin cervical test

784 SICCT: intradermal cervical comparative tuberculin test

785 SICT: intradermal cervical tuberculin test (it can be an SSICT or an SICCT)

786

Appendix F. Results of the multivariable logistic regression explaining the restraining help variable

AUC of ROC analysis: 0.6976 [0.6014-0.7938]$_{CI95\%}$

		Estimated coefficient	Standard error	p-value	Reference category
Constant		-0.979	0.915	0.228	/
Veterinarian's sex		0.868	0.523	0.0970	Woman
Proportion of SICTs among the ICTs performed by the veterinarian		-0.0120	0.00639	0.0608	/
Prevalence of restraining corridors in the vet. customers' farms (prevalent/less prevalent)		0.929	0.432	0.0314*	Less prevalent
Screening rhythm in the area	Biennial or triennial	-1.00	1.17	0.0993	Annual
	Stopped	-0.825	0.949		
	Zoning [(1)]	0.284	0.848		

*p < 0.05, significant association.

[(1)] Zones are defined around outbreaks in which annual screening is performed regardless of the screening rhythm in the rest of the area.

Appendix G. Results of the simple logistic regressions explaining the frequency of headlocks

Predictor variable	p-value	Comment on the predictor variable
Main production type among the veterinarian's customer's farms	0.63	Categorical (dairy/beef/mixed)
Herd size	0.50	Continuous
Maximal screening rhythm in the areas were the veterinarian works	0.86	Categorical (annual, biennial or triennial, stopped or zoned)
Prevalence of bTB in the areas were the veterinarian works	0.58	Categorical (bTB free or 1 to 5 breakouts more than 5 years ago, infected (1 to 10 breakouts in the last 5 years), highly infected (more than 10 breakouts in the last 5 years)

**significant with α = 0.01, included in the multivariable analysis

*non-significant, but p < 0.25, so included in the multivariable analysis

Appendix H. Summary of Churchill's paradigm for developing a measurement tool in social science (Churchill, 1979)

Invalid measure

Unreliable measure

Steps of the development process	**Coefficients or evaluation technique**
1- Define the studied concept	Literature review, free interviews
2- Generate a sample of variables potentially usable to measure this concept	Literature, introspection, individual semi-directive interviews, etc.
3- Primary data collection	N >3 0, on a sample with characteristics close to those of the population of interest
4-"Purification" of the measure: suppress the variables that digress from the subject	Cronbach's Alpha coefficient(1), Split-half(2), principal component analysis
5- Data collection	N > 200
6- Assess the reliability of the measure	Cronbach's Alpha coefficient(1), Split-half(2)
7- Asses the validity of the measure	Discriminant(3) and convergent(4) validity procedure and nomological(5) validation

(1) $\alpha = \frac{k}{k-1} * \frac{1-k}{k+2\sum_{ij}^{n} rij}$ in which k is the number of variables, n the sample size and rij the correlation coefficient between the variables i et j (Cronbach, 1951). Alpha is between zero and one. If α = 0, the correlations between variables are null and therefore the measurement tool is not reliable because there is no internal coherence. On the contrary, if α = 1, the measure is perfectly reliable. Reliability is considered satisfying if α > 0.7 (Nunnally, 1967).

(2) The sample is randomly divided into two sufficiently large parts, the results of the measurements obtained for the two samples and the global sample must be very close.

805 (3) Two measures of two different and independent concepts must produce uncorrelated results.

806 (4) Two measures of the same concept must produce convergent (highly correlated) results.

807 (5) The two measures of two different but theoretically linked concepts must recapitulate both the

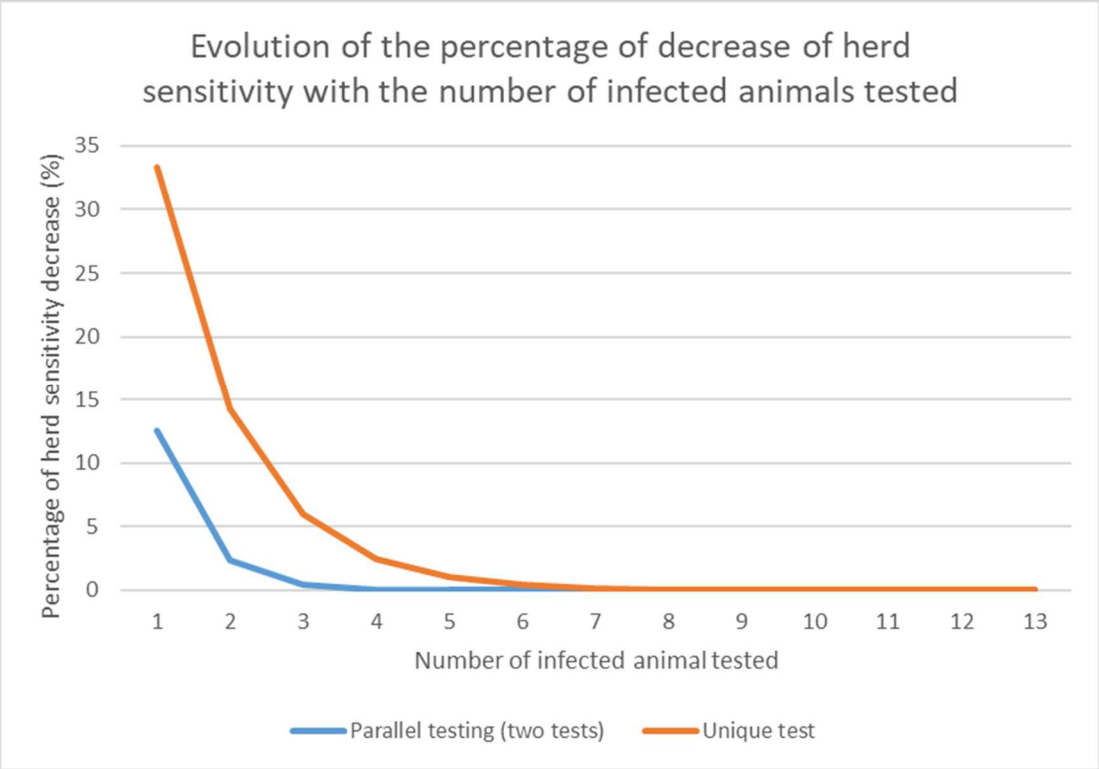
808 direction and the intensity of this link.

809

810 *Appendix I. Evolution of the percentage of the decrease of herd sensitivity of two protocols: one using a unique test and the*

811 *other using parallel testing, with the number of infected animals tested using a test with an initial sensitivity of 80% that has*

812 *decreased to 60%.*



813

814 Formulas (1) and (2) were used to calculate the percentage of the decrease (D) of herd sensitivity for

815 the unique test protocol and parallel testing, respectively for which Se = an initial test sensitivity of

816 80% and Se'= a decreased sensitivity of 60%, with n the number of infected animals tested.

817 (1) $D_{unique}=\frac{(1-(1-Se)^n)-(1-(1-Se')^n}{1-(1-Se)^n}$

(2) $D_{parallel}=\frac{\left(1-(1-Se)^{2n}\right)-(1-(1-Se')^{2n}}{1-(1-Se)^{2n}}$

Figure 1. Scenario tree incorporating factors related to veterinarians' SICCT and notification practices used to model the strict regulatory protocol.

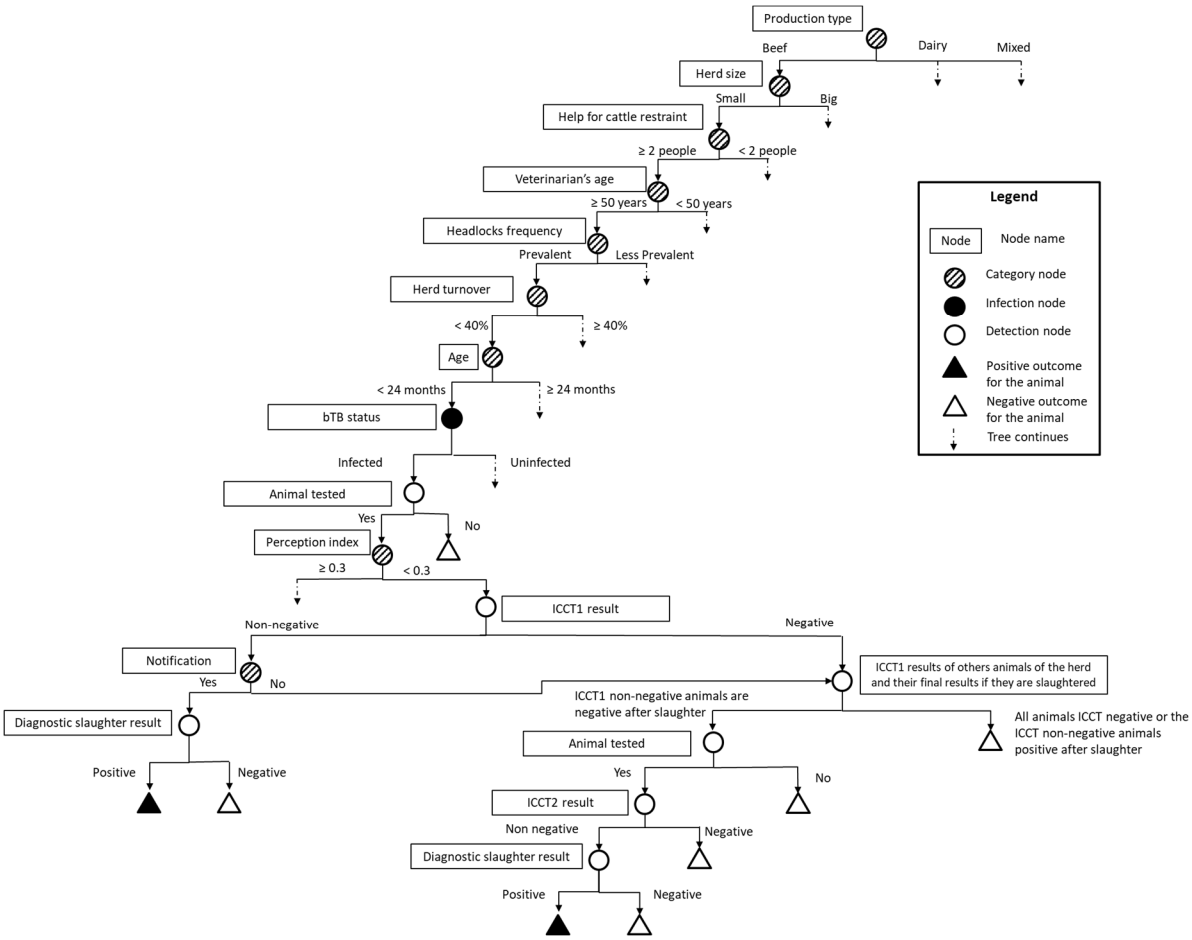


Figure 2. Scenario tree incorporating factors related to veterinarians' SICCT and notification practices used to model the compliant quick-path regulatory protocol

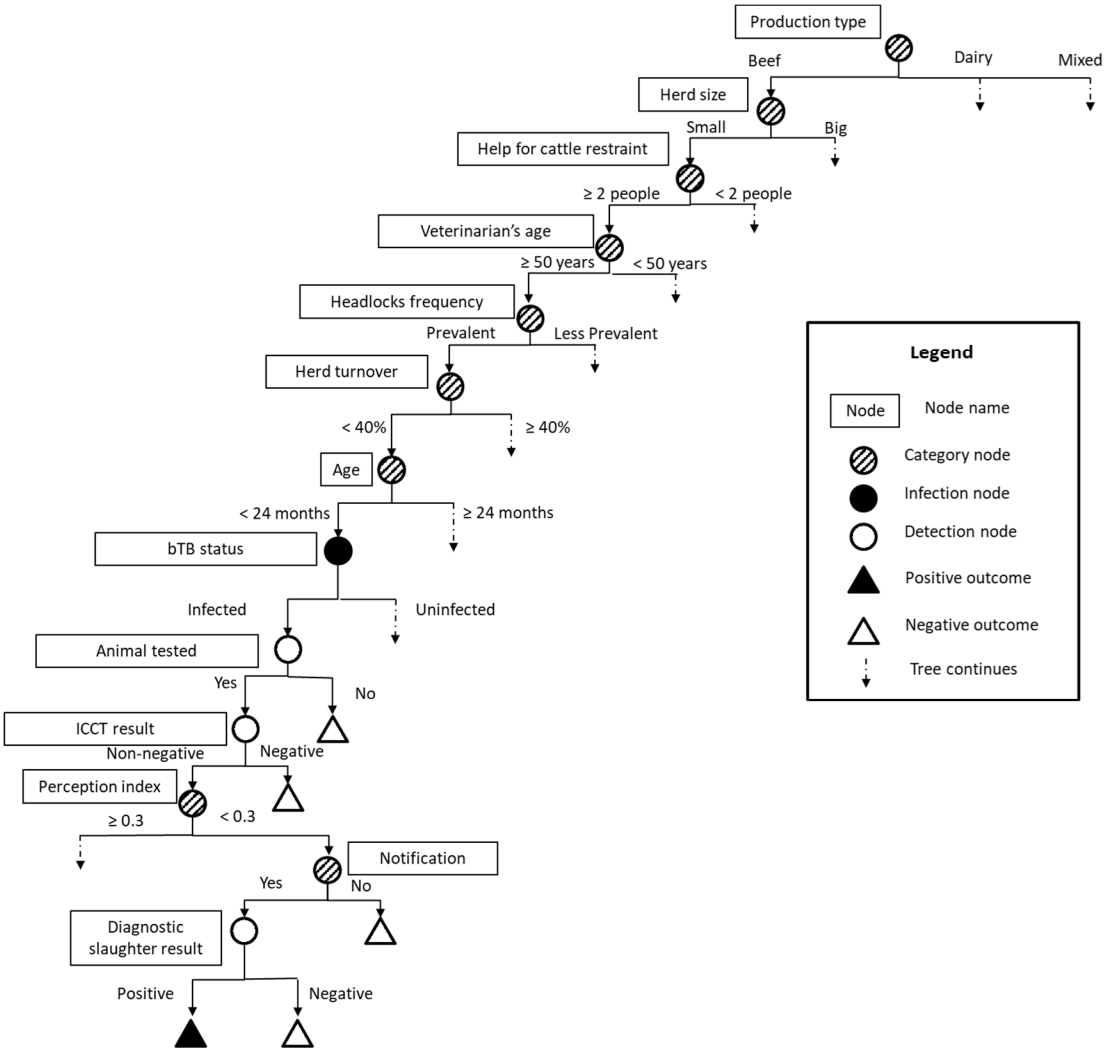


Figure 3. Scenario tree incorporating factors related to veterinarians' SICCT and notification practices used to model the compliant slow-path regulatory protocol

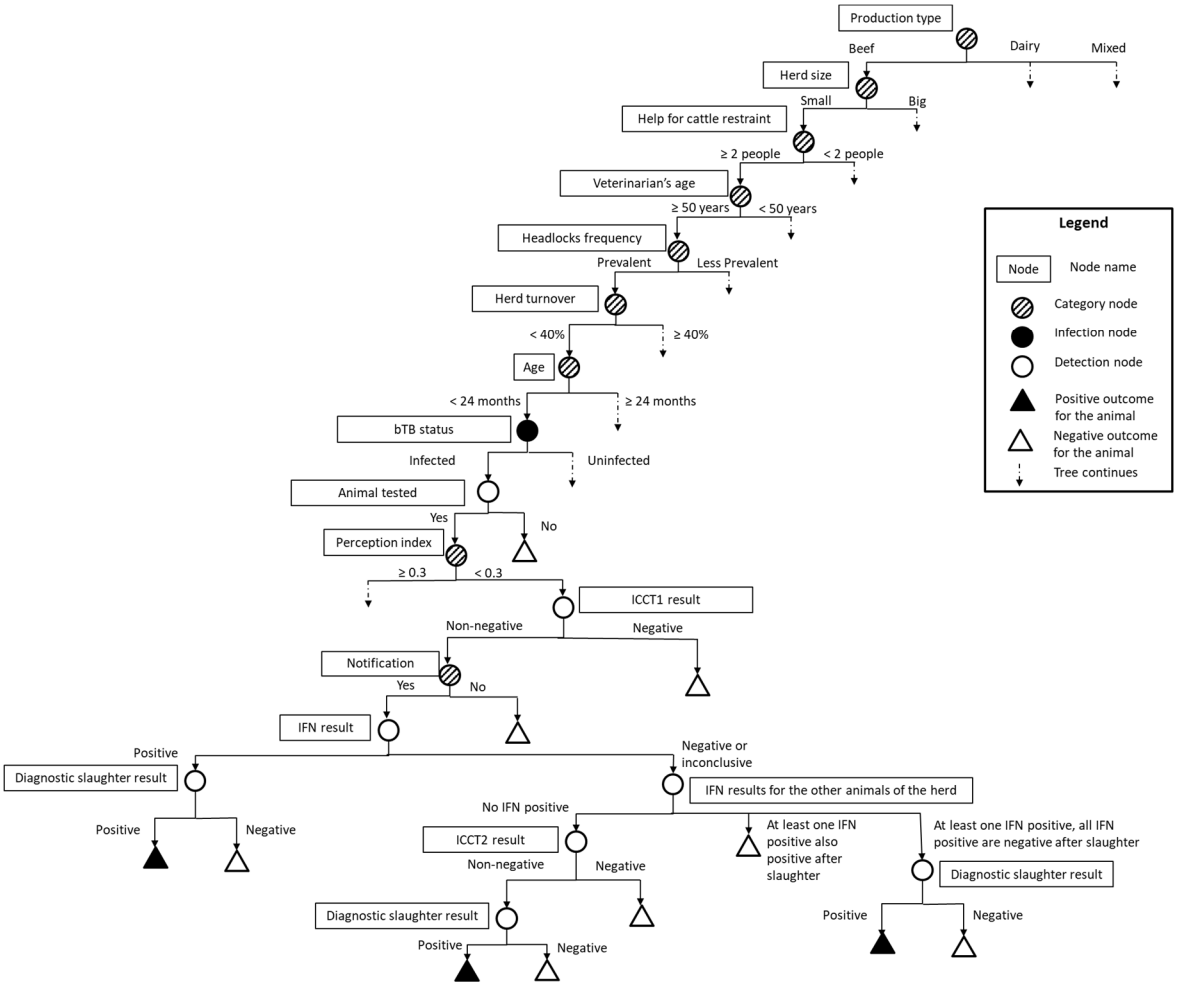
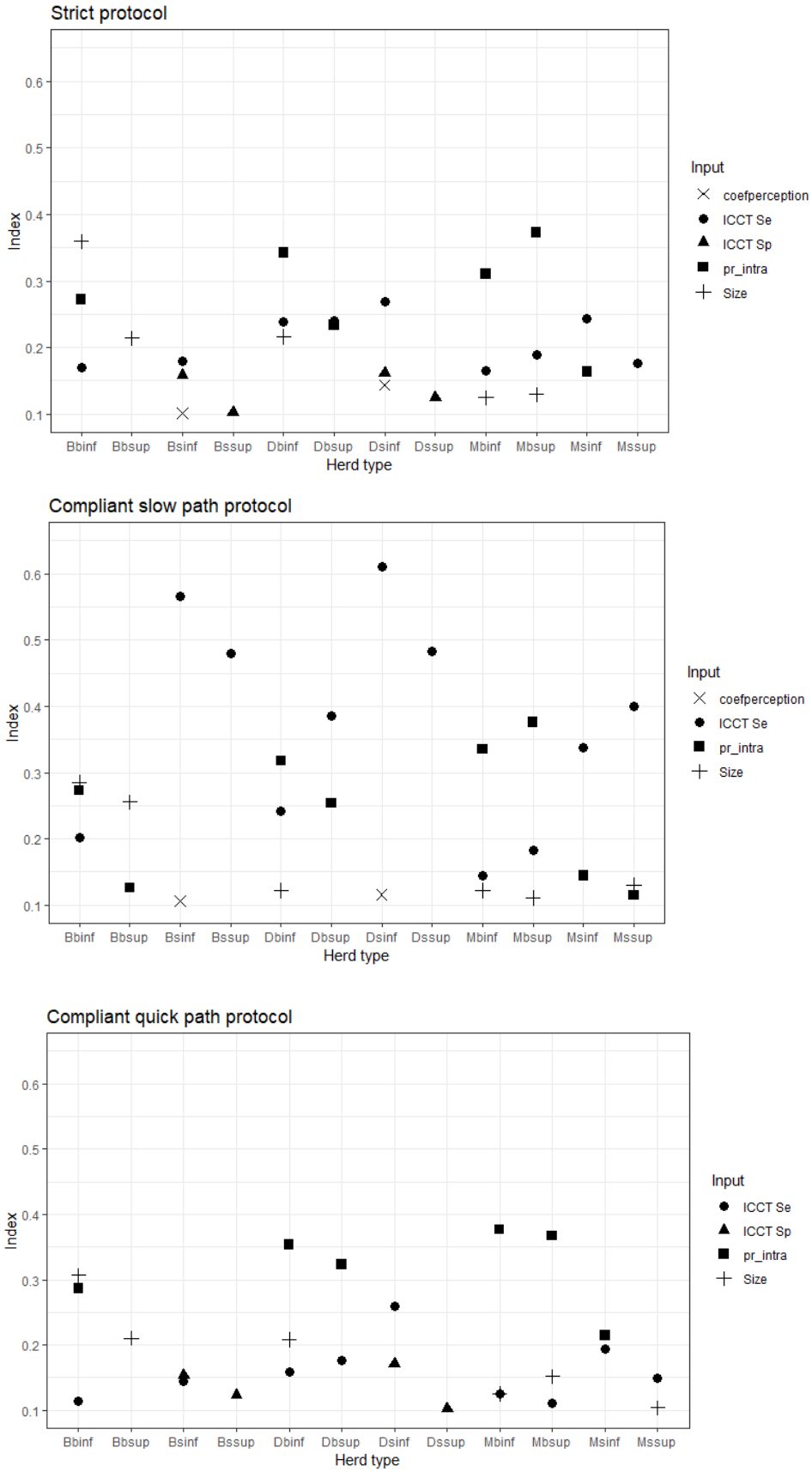


Figure 4. Sensitivity analysis index above 10% (Mc Kay method) for the output "herd sensitivity" by herd type for each protocol



Legend:

Bbinf: big beef farm with a turnover < 40%, Bbsup: big beef farm with a turnover > 40%, Bsinf: small beef farm with a turnover < 40%, Bssup: small beef farm with a turnover > 40%, Dbinf: big dairy farm with a turnover < 40%, Dbsup: big dairy farm with a turnover > 40%, Dsinf: small dairy farm with a turnover < 40%, Dssup: small dairy farm with a turnover > 40%, Mbinf: big mixed farm with a turnover of < 40%, Mbsup: big mixed farm with a turnover > 40%, Msinf: small mixed farm with a turnover of < 40%, Mssup: small mixed farm with a turnover > 40%.

Coefperception: perception index
SICCT Se: sensitivity of the intradermal cervical comparative tuberculin test,
SICCT Sp: specificity of the intradermal cervical comparative tuberculin test,
pr_intra: within-herd prevalence of bovine tuberculosis,
Size: herd size.

Table 1. Points attributed to the veterinarians, according to their answers to the quantitative online survey, to develop the ICCT practice index (adapted from Crozet et al. in press)

*Legend: **0** = in agreement with recommendations or acceptable practices, **1** = unacceptable practices*

	Score	Relative contribution towards the risk of obtaining a false negative result for the ICCT *(Humblet, 2011)*	Weight*
Injection site			
Always on the neck	0	7.0%	1
Neck only for non-nervous cattle, no skin test for others	0		
Neck only for non-nervous cattle, other injection site (*e.g.* caudal fold) for others	0		
No skin test if nervous cattle are present	1		
Other injection site (*e.g.* caudal fold) for all animals	1		
Preparation of the injection site			
Scissors	0	6.0%	0.5
Clipper	0		
Razor	0		
Marking without cutting hair (e.g. marker)	0		
Variable	1		
No preparation	1		
Injection tool			
Syringe and needle	0	3.0%	0.5
McLintock™	0		
Muto™	0		
Synthena™	0		
Dermojet™	1		
Injection quality check			
Systematic check of tuberculin release and reinjection, if present, with a quantity adjusted to the estimated release	0	10.2%	1
Systematic check of tuberculin release and reinjection if present with a full tuberculin dose	0		
Systematic check of tuberculin release but no reinjection, if present (because of drudgery)	1		
No check of tuberculin release	1		
Systematic check of tuberculin release but no reinjection, if present (because of fear of a false-positive reaction)	1		
Person performing reading of the skin test results			
Always the same veterinarian as the one who injected	0	7.9%	1
Occasionally a different veterinarian from the one who injected	1		
Reading time			
Postponed to the day after if impossible at Day 3	0	7.9%	1
Performed earlier if impossible at Day 3	1		
Reading method in case of difficulties in handling the cattle			
Following regulatory recommendations	0	19.4%	2
Visual examination only	1		
Reading method			
Measurement of skin folds at the 2 injection sites before injection and comparison with the 2 measurements performed at Day 3	0	19.4%	2
Measurement of skin fold at only one site before injection and comparison with measurements performed at the 2 injection sites at Day 3	0		
Measurement of skin folds at the 2 injection sites before injection and comparison with the 2 measurements performed at Day 3 only if there is a palpable reaction	0		
No measurement before injection, 3 measurements at Day 3: 2 at the injection sites compared to a measurement of a non-injected site	1		

*Category of the influence of the risk to obtain a false negative result for the ICCT during performance of the test *(Humblet, 2011)* (in %) and associated weight:]0%-7%[⇒ weight = 0.5, [7%-15%[⇒ weight = 1, [15%-22%[⇒ weight = 2.

Note: this table was extracted from Crozet et al. 2019 and adapted for our study. The second and last columns were modified.

Table 2. Points attributed to the veterinarians, according to their answers to the quantitative online survey, to develop the perception index representing their perception of the bTB surveillance and control program

Legend:

0: answer associated with a positive perception; 1: answer associated with a negative perception.

Points were summed and rescaled to range from 0 to 1.

	Score
Major consideration in case of non-negative result obtained for skin testing	
Thinks of a potential outbreak of a zoonotic disease	0
Thinks of a potential outbreak with major economic impact for the farmer	0
Thinks of potential temporary and useless blocking of the farm (false-positive result)	1
Has no specific consideration	1
Concerning intradermal skin tests	
Has necessary information from sanitary authorities	Yes = 0 / No = 1
Perceives him/herself as able to properly perform skin tests	Yes = 0 / No = 1
Thinks a knowledge update on skin tests is necessary	Yes = 1 / No = 0
Thinks intradermal skin tests are the best available screening tests	Yes = 0 / No = 1
Thinks the interpretation of skin tests is too subjective	Yes = 1 / No = 0
Thinks it is necessary to re-evaluate the administrative part associated with skins tests during screenings (reporting of measurements, transmission of results, etc.)	Yes = 1 / No = 0
Thinks it is necessary to adapt regulatory recommendations to realities of the field	Yes = 1 / No = 0
Thinks it is necessary to stop blocking herds for 6 weeks in case of a non-negative result	Yes = 1 / No = 0
Concerning hurdles to eradicating bovine tuberculosis	
Highlights limitations of single intradermal skin tests	Yes = 1 / No = 0
Highlights limitations of single intradermal comparative cervical skin tests	Yes = 1 / No = 0
Highlights possible role of wildlife reservoir	Yes = 1 / No = 0
Highlights a lack of consideration from sanitary authorities	Yes = 1 / No = 0
Highlights the low fees paid for skin tests	Yes = 1 / No = 0
Highlights the danger of performing skin tests	Yes = 1 / No = 0
Highlights the dual role of private practitioner and sanitary veterinarian *	Yes = 1 / No = 0
Concerning the bovine tuberculosis control program	
Essential because it is a major zoonotic infection	Yes = 0 / No = 1
Essential to keep an official tuberculosis-free status	Yes = 0 / No = 1
Essential to prevent the circulation of infectious agents in cattle herds	Yes = 0 / No = 1
Essential to end the eradication effort initiated decades ago	Yes = 0 / No = 1
Useless, because the bovine tuberculosis situation is favourable	Yes = 1 / No = 0
Useless, because such a program will never have good results	Yes = 1 / No = 0

* In France, private veterinarians are empowered by the State to perform regulatory testing and investigations on the farms in which they usually work. Therefore, veterinarians have a dual role: one as a private veterinarian and another as a State agent.

Table 3. Method used to calculate the sensitivity and specificity of the SICCT in the scenario trees depending on the SICCT practice index value

	ICCT practice index				
	0	]0-3]	]3-6]	]6-10]	> 10
Sensitivity	literature: Se	0.75*Se	0.5*Se	0.25*Se	0
Specificity	literature: Sp	Sp+(1-Sp)*0.25	Sp+(1-Sp)*0.5	Sp+(1-Sp)*0.75	1

For the first screening SICCT, Se was modelled using a normal asymmetric distribution law, with a mean of 74%, and 95% of the values between 43% and 95%; Sp was modelled using a normal asymmetric distribution law, with a mean of 99%, and 95% of the values between 80% and 100% (Poirier et al., 2019).

Table 4. Results of the multivariate linear regression explaining the SICCT practice index

Adjusted $R^2 = 0.2187$
F statistic = 5.806
Model's p-value < 0.001
Residual standard error = 1.426 (degrees of freedom = 97)

		Estimated coefficient	Standard error	p-value	Reference category
Constant		0.97	0.490	0.05*	/
Perception index		4.47	1.188	$2.85.10^{-4}$**	/
Veterinarian's age (< 50, ≥ 50 years)		0.573	0.293	0.054	<50 years
Production type	Dairy	-0.1467	0.398	0.0766	Beef
	Mixed	-0.805	0.351		
Prevalence of restraining corridors in the vet. customers' farms (prevalent/less prevalent)		0.698	0.283	0.0155*	Less prevalent
Proportion of SSICTs among the SICTs performed by the veterinarian		0.0082	0.004354	0.0626	/

**p < 0.01, significant association
*p < 0.05
SSICT: single intradermal tuberculin cervical test; SICCT: intradermal tuberculin cervical comparative test; SICT: intradermal cervical tuberculin test

Table 5. Results of the univariate linear regression explaining the SICCT practice index by the perception index

Adjusted $R^2 = 0.1063$
F statistic = 13.25
Model's p-value < 0.001
Residual standard error = 1.526 (degrees of freedom = 102)

	Estimated coefficient	**Standard error**	**p-value**	**Reference category**
Constant	1.7963	0.3933	1.38×10^{-5}**	/
Perception index	4.3708	1.208	4.3×10^{-4}**	/

**p < 0.01, significant association
SICCT: intradermal cervical comparative tuberculin test

Table 6. Results of the multivariate linear regression explaining the perception index

Adjusted R^2 = 0.2142
F statistic = 6.181
Model's p-value = $1.34*10^{-5}$
Residual standard error = 0.1068 (degrees of freedom = 108)

		Estimated coefficient	Standard error	p-value	Reference category
Constant		0.4086	0.0214	$< 2.10^{-16}$**	/
Veterinarian's age (< 50, ≥ 50)		-0.07047	0.0223	0.00206**	< 50 years
Veterinarian's status (employee/self-employed)		-0.05977	0.0288	0.0406*	Self-employed
Headlock frequency (prevalent/less prevalent)		-0.06543	0.0212	0.00252**	Less prevalent
Restraining help (<2 people / ≥2 people)		-0.06583	0.0203	0.00156**	< 2 people
Production type	dairy	-0.05730	0.0279	0.0566	Beef
	mixed	0.01928	0.0256		

**p ≤ 0.01, significant association
*p < 0.05

Table 7. Results of the multivariate logistic regression explaining the notification of non-negative results.

AUC of ROC analysis: 0.849 [0.77-0.92]$_{CI95\%}$

		Estimated coefficient	Standard error	p-value	Reference category
Constant		5.03	1.7	$1.8.10^{-5}$**	/
Perception index		-9.03	-1.94	0.03*	/
bTB cumulative incidence for 1 000 herds between 2012 and 2016 in the areas were the veterinarian works	≤ 0.1	18.08	1888.62	0.1	]0.1,1]
	]1-10]	0.76	0.73		
	> 10	1.769	1.40		

*p < 0.05, significant association.

Table 8. Mean and standard deviation of the perception index in the database, according to the veterinarian's age, number of people usually helping to restrain the cattle during the ICCT and headlocks frequency; and parameters of the corresponding beta laws used to model the perception index of veterinarians

Veterinarian's age	Help during cattle handling	Headlocks frequency	Mean	sd	Beta law's parameters	
					a	b
< 50 years	< 2 people	Less prevalent	0.37	0.14	4.03	6.86
		prevalent	0.32	0.13	3.80	8.07
	≥ 2 people	Less prevalent	0.31	0.14	3.07	6.84
		prevalent	0.25	0.09	5.54	16.61
≥ 50 years	< 2 people	Less prevalent	0.33	0.10	6.97	14.14
		prevalent	0.27	0.08	8.05	21.75
	≥ 2 people	Less prevalent	0.26	0.08	7.56	21.51
		prevalent	0.22	0.12	2.40	8.52

Table 9. Parameters of the beta distribution law used for the probability that the veterinarian notifies a non-negative result for an ICCT according to perception index category

Perception index[1]	Notification of ICCT non-negative results	a	b
< 0.30	Yes	60	1
	No	Complementary to 1	
≥ 0.30	Yes	49	6
	No	Complementary to 1	

[1] The categories were defined according to the mean perception index of 0.303 observed in our data.

Table 10. Herd sensitivity estimation (in %) for each protocol by herd type

Herd production type	Herd size category	Herd turnover	Compliant slow-path protocol		Compliant quick-path protocol		Strict protocol	
			Mean	95% CI	Mean	95% CI	Mean	95% CI
Dairy farm	small (< 74 adults)	< 40%	25.2	25.1-25.3	25.7	25.6-25.9	32.3	32.2-32.4
		≥ 40%	18.5	18.4-18.5	18.4	18.3-18.4	24.3	24.2-24.4
	big (≥ 74 adults)	< 40%	32.0	31.8-32.2	33.2	33.0-33.5	36.6	36.3-36.8
		≥ 40%	24.8	24.7-25.0	25.4	25.3-25.6	29.8	29.7-29.9
Beef farm	small (< 66 adults)	< 40%	22.3	22.2-22.4	22.5	22.4-22.6	29.2	29.1-29.3
		≥ 40%	19.1	19.0-19.2	19.1	19.0-19.2	25.3	25.2-25.4
	big (≥ 66 adults)	< 40%	30.5	30.3-30.8	31.6	31.3-31.8	35.1	34.9-35.4
		≥ 40%	13.8	13.7-13.9	12.7	12.6-12.8	18.4	18.2-18.5
Mixed farm	small (< 124 adults)	< 40%	26.4	26.3-26.6	27.2	27.0-27.4	31.9	31.7-32.0
		≥ 40%	22.9	22.8-23.0	23.3	23.2-23.4	28.8	28.6-28.9
	big (≥ 124 adults)	< 40%	46.2	45.8-46.5	48.6	48.2-48.9	50.8	50.4-51.1
		≥ 40%	41.7	41.4-42.0	43.7	43.4-44.1	46.2	45.9-46.6

Table 11. Impact of the incorporation of ICCT and notification practices in the sensitivity estimation of regulatory protocols

Herd production type	Herd size category	Herd turnover	Compliant slow-path protocol			Compliant quick-path protocol			Strict protocol		
			Socio - (%)[1]	Socio + (%)	Decrease of herd sensitivity (%)[2]	Socio - (%)[1]	Socio + (%)	Decrease of herd sensitivity (%)	Socio - (%)[1]	Socio + (%)	Decrease of herd sensitivity (%)[2]
Dairy farm	small (< 74 adults)	< 40%	42.7	25.2	**41**	44.2	25.7	**42**	47.4	32.3	**32**
		≥ 40%	30.8	18.5	**40**	31.6	18.4	**42**	34.3	24.3	**29**
	big (≥ 74 adults)	< 40%	49	32.0	**35**	51.6	33.2	**36**	52.3	36.6	**30**
		≥ 40%	40.4	24.8	**39**	42.4	25.4	**40**	43.7	29.8	**32**
Beef farm	small (< 66 adults)	< 40%	37.5	22.3	**41**	38.7	22.5	**42**	41.8	29.2	**30**
		≥ 40%	32	19.1	**40**	32.9	19.1	**42**	35.6	25.3	**29**
	big (≥ 66 adults)	< 40%	46	30.5	**34**	48.2	31.6	**34**	49.1	35.1	**29**
		≥ 40%	20.2	13.8	**32**	20.8	12.7	**39**	21.7	18.4	**15**
Mixed farm	small (< 124 adults)	< 40%	43	26.4	**39**	45.1	27.2	**40**	46.6	31.9	**32**
		≥ 40%	37.7	22.9	**39**	39.3	23.3	**41**	41.2	28.8	**30**
	big (≥ 124 adults)	< 40%	61	46.2	**24**	63.9	48.6	**24**	64.2	50.8	**21**
		≥ 40%	56.8	41.7	**27**	59.6	43.7	**27**	59.9	46.2	**23**

Legend: Socio -: estimation by scenario-tree modelling without accounting for the sociological data concerning the intradermal cervical comparative tuberculin test (ICCT) and non-negative ICCT result notification; Socio + : estimation by scenario-tree modelling accounting for the sociological data concerning the intradermal cervical comparative tuberculin test (ICCT) and non-negative ICCT result notifications

[1] Poirier *et al.* 2019, under review

[2] Proportion of sensitivity estimation decrease resulting from the incorporation of data concerning ICCT and notification practices.