An experts' opinion-based comparison and benefit cost analysis of post-mortem versus tuberculin skin test surveillance systems, Mpumalanga, South Africa

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Keywords: bovine tuberculosis, benefit cost analysis, Mpumalanga, surveillance, zoonosis

Posted Date: June 17th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-34964/v1

Abstract

Background

Tuberculosis (TB) is a global health concern caused mostly by *Mycobacterium bovis (M. bovis)* and *Mycobacterium tuberculosis* (*M. tuberculosis*) in animals and humans respectively. As part of TB control strategies, most governments instituted test and slaughter policies for bovine TB (bTB) eradication with varied level of success.

Methods

Using the SurvCost® (http://www.cdc.gov/idsr/survcost.htm), we evaluated the postmortem surveillance (PMS) system as an alternative to the tuberculin skin test (TST). Experts'opinions survey was used to collect information on the perceived level of acceptability of PMS and TST, successes and challenges of both surveillance systems, economic and budget data. Benefit cost analysis of both systems were evaluated and the comparative economic benefit of PMS over TST was determined.

Results

TST implementation was challenging due to poor logistics, procurement challenge, poor feedback, inconsistency in testing and poor return rate for retesting. Experts agreed that PMS was cheaper but almost impracticable due to late detection and probable poor compliance rate but farmers were more open to PMS than TST. Personnel cost remains the largest part of the surveillance cost (47.8% of total costs). TST and PMS systems can be up to 4.40 and 5.96 times more beneficial that not tackling bTB respectively and PMS is 1.35 more cost beneficial that TST.

Conclusion

While TST is empirical, compliance by farmers was poor due to the associated inconveniences. In the alternative, PMS was convenient for farmers but experts believed that adherence will be poor unless increased manpower is available. We advocated for a blended approach between the two systems. Improved field surveillance and detailed economic data should benefit future economic assessment.

Trial registration

Not applicable.

Background

Mycobacterium bovis (*M. bovis*) is the causal agent for bovine tuberculosis (bTB), an infectious and chronic disease of livestock, wildlife and humans [1,2]. *M. bovis* is a significant pathogen due to its conservation threat (wildlife infections), economic implication (cattle disease), and zoonotic importance. Bovine TB remains a worldwide problem, therefore it is imperative to intensify control and preventive measures in livestock aimed at its eradication [3].

The TST is recognised universally and used for preliminary diagnosis in bTB control programmes [4]. Other tests include antibody ELISAs and Bovigam®™ (a commercial IFN-g assay), used as ancillary tests in eradication and control of bTB [4]. In South Africa the TST is accepted as the standard field test for diagnosis in bTB control programmes. The advantages of the TST and reasons for its extensive use are low costs, relatively better accessibility of tuberculin purified protein derivative (PPD), history of successful use, and the lack of better alternative methods to detect bTB [5]. Despite these advantages the skin test has many known limitations, including the difficulties in field administration and interpretation of results, the need for a supplementary visit to measure the skin response and associated non-compliance by farmers, a low degree of standardisation, and imperfection associated with test accuracy [5,6]. As such, its field application appears unpopular among the field veterinarians and their para-veterinary staff [7].

Eradication of bTB from cattle in some countries has been unexpectedly protracted, and this has raised questions about the effectiveness of skin testing, particularly when the incidence of disease in the population is low or where there is the potential for contact with environmental mycobacteria. Given the above, recent research has focused on developing alternative, innovative, and complementary testing procedures [2,8].

It has been shown that in countries with low bTB, disease prevalence or disease-free status, meat inspection is effective as a diagnostic and surveillance tool [4]. The importance and impact of meat inspection as a diagnostic and preventive tool cannot be overemphasized. In addition to providing epidemiological information on life threatening zoonotic diseases of meat-borne origin, such as bovine TB, brucellosis, and other toxicoinfections (such as salmonellosis), it also ensures standards for hygienic and wholesome meat free from infections and other toxicoses of inorganic sources are met and upheld [9].

In 2015, Musoke and colleagues performed a bTB surveillance study on cattle in the Mnisi Community, based in the Bushbuckridge District Municipality, Mpumalanga province, South Africa [10]. They found a low prevalence (approx. 0.34%, excluding suspect animals) of bTB in the cattle population. This low prevalence in cattle may justify the use of point-of-slaughter postmortem evaluation in communal areas for diagnosis and surveillance. VanderWaal et al. [11] studied different surveillance strategies such as PMS and targeted testing as alternatives to routine skin testing in low TB prevalence settings. They found that targeted surveillance was more cost effective and reduced sampling effort by 40% without increasing the incidence of bTB.

Currently, in the Mnisi Community in the Bushbuckridge Municipality of Mpumalanga province, the TST surveillance in cattle is minimally applied due to high costs and unwillingness to conduct the difficult TST by technicians (personal communication with professionals). This is not an unusual phenomenon. O'Reilly & Daborn [1] have noted that the TST is not always performed as recommended because of management conditions that make it difficult to perform. Furthermore, bTB TST evaluation has focused on cattle [12; other livestock species such as goats and sheep have been neglected though they are susceptible to *M. bovis* [13].

In some parts of Africa, bTB detection has depended on slaughter surveillance as the most economical and efficient method for the detection of infected cattle [14]. Meat inspection at abattoirs is thus considered as a pivotal and the utmost obligatory method for the detection of bTB or other mycobacterial infections [14]. In view of the foregoing and considering that such PMS systems, which are seen as cheaper and easier to perform, are adapted to rural communities at the point of personal slaughter and not just at the abattoirs, we sought to investigate if this would be a more cost effective and efficacious detection method for TB surveillance versus the current bTB TST in the Mnisi Community which has achieved poor compliance in TST? Also, would the veterinarians and para-veterinarians consider this procedure a less laborious and easily adaptable method? Outcome can serve as a proof of concept to geographical terrains with similar situations.

Materials And Methods

Expert opinion survey

To get a representative opinion of the acceptability of the proposed postmortem surveillance system, a questionnaire directed at government officials (veterinary directors, state veterinarians and technicians) from all nine provinces of South Africa was developed. Questionnaires were administered by email or by telephonic interview. It included open-ended and closed questions, which focused on the current budget for TST surveillance, challenges faced with the surveillance program, opinion on an incentive-based PMS system and a panel of questions on logistic and other issues that support the application and administration of the current programme.

Benefit cost analysis

Budget data were obtained from the State Veterinary services. Additional prevailing economic data were retrieved either through field survey or personal interviews with the stakeholders in the industry. Population and other demographic data as well as prevalence of TB in Mnisi, Mpumalanga or South Africa were obtained through literature review and from the website of Statistics South Africa (www.statssa.gov.za). Using budget information from State Veterinary services, all costs (recurrent, operational and capital expenditure) were calculated under different cost heads (Supplementary data). An annual summary of all costs was generated as outputs, and an integrated disease surveillance cost for TB was produced based on field data using the SurvCost®, an Excel-based analysis tool (http://www.cdc.gov/idsr/survcost.htm). Integrated Disease Surveillance and Response System (IDSR) is a system whereby all diseases of interest in an area through passive or active surveillance are reported together using the same human, capital and infrastructure resources already available to the area [15]. SurvCost® uses this system to estimate surveillance costs of diseases of interest. Outputs were generated in tables and graphs. Comparative costs and effectiveness were evaluated using the benefit cost analyses of overall estimated surveillance costs using TST and PMS.

Results

Expert opinion survey

Ten experts that included directors of veterinary services, state veterinarians and animal health technicians (AHT) in the South African Veterinary Services participated in the expert opinion survey. A response rate of 67% was obtained. In view of the sensitivity of budget matters, and stringent rules regarding non-disclosure, it was a challenge to obtain some detailed budget information from technical experts. While some feigned ignorance or referred the researcher to higher authorities, others ignored the question completely. However, detailed information was obtained from two provinces and this formed the basis for comparison and validation of economic data.

Ninety percent of all experts had a bTB surveillance program operational in the areas covered by their operations. The TST is most used as recommended by DAFF for South African Veterinary Services [16].

The main challenges of the TST reported by participants include among others: poor logistics in the implementation of the herd testing program, centralised and red tape in the procurement system for reagents (tuberculin), lack of timeous feedback to central agency (DAFF) and no consistency in frequency of testing.

Overall, 90% of all experts suggested that a PMS system is impracticable and not good for adoption. Reasons advanced for opposing the PMS were: it detects infection very late and so may enhance spread, farmers would use their own resources to report pending slaughter and this might result in low compliance, slaughter rates are low, there will be too many homesteads to follow up, attitude of farmers varies and there are illiterate farmers who may not take the strict implementation seriously, manpower and transport would be a challenge, and that some mortalities may not be reported.

The experts agreed that the TST is not being implemented effectively due to the above cited challenges, but do not see PMS as a viable and practical alternative.

Benefit Cost Analysis

Using SurvCost®, an integrated disease surveillance and response system implemented for TST will cost R1,783, 242 per annum for the Mnisi Community with an average cost of R84.33 per animal. Specifically, 35.4% of the cost will be for personnel, 16.0% for office support, 7.5% for transport, 30.9% for test sundries (i.e tuberculin ,syringes, gloves), 0.2% for treatment and 9.9% as capital cost (Table 1, Figures1 and 2). For a similar programme implemented for PMS, the overall cost will reduce to R1,320,361 per annum with an average cost of R62.44 per animal. In this case, 47.8% of the cost will be for personnel, 21.7% for office support, 15.6% for transport, 1.3% for test sundries, 0.3% for treatment and 13.4% as capital cost (Table 1, Figures 1 and 2).

In both graphs, (Figures 2 & 3, Supplementary material), personnel costs were the highest by proportions. In TST surveillance, the costs of tuberculin added significantly to the test sundries cost while in PMS, the test sundries costs decrease proportionately to approximately 1% since there was no need for the skin test. However, the cost for transport increased proportionately in PMS due to costs incurred in door to door communal slaughter postmortem inspections. Overall, in this study, the PMS model appears cheaper than the TST model.

The 2017 estimates of cattle population in Mnisi will be 21,145 and at a 3.1% prevalence of bTB in cattle, approximately 656 heads of cattle will be infected (Musoke et al., 2015); at a market value of approximately R12 000 per cow, a hypothetical 100% rejection of infected cattle population will result in losses of R7,872,000. Even, at 50% or 25% rejection rates, assumed losses will amount to R3,936,000 or R1,968,000 respectively (Table 2). Through the integration of TST and PMS, the benefit cost ratio will be 4.41 or 5.96 respectively. While it is evident that conducting the annual surveillance is better in both respects using TST or PMS, the latter (PMS) was at least 1.35 fold economically cost beneficial compared with TST (Table 2). Below a 25% rejection rate of the infected animals, the surveillance system becomes non-beneficial for implementation in the Mnisi Community. Similarly, surveillance using

TST or PMS based on visceral (lungs and livers) rejection alone cannot justify the investment as inputs far outweigh the expected benefit. (Table 2). Additional benefits including the deduction in risk of transmission to other animals and prevention of 339 potential human cases were not quantified in this analysis.

Table 1. SurvCost® cost analysis for TST and PMS for bovine tuberculosis based on inputs from experts

Category		Current TST system costs		Proposed PMS system cost	
		All disease surveillance cost (ZAR)	TB IDSR cost (ZAR)	All disease surveillance cost (ZAR)	TB IDSR cost (ZAR)
Recurrent costs	Personnel	1 490 587	630 902	1 491 956	630 902
	Office	722 274	286 009	722 274	286 009
	Transport	356 375	134 389	365 375	205 896
	Laboratory /Test sundries	637 397	551 217	56 100	16 830
	Treatment	49 564	4371	49 564	4 371
Capital costs	Buildings	38 876	5831	38 876	5 831
	Vehicles	365 389	170 522	365 389	170 522
All resources		3 661 831	1 783 242	3 080 534	1 320 361
Cost per animal		173.18	84.33	145.69	62.44

PMS = postmortem surveillance and TST = tuberculin skin test system

Table 2. Benefit-cost analysis of comparison between postmortem surveillance (PMS) and tuberculin skin test (TST), Mpumalanga, South Africa

s/no.	Items	PMS (in ZAR)	Total (in ZAR)	Benefit/ cost (PMS)	TST (in ZAR)	Total (in ZAR)	Benefit/ cost (TST)	Comments/Additional benefits	Source(s) of information
1	Cost of surveillance for TB/animal/annum	62.44			84.33				SurvCost® analysis, this work
2	Total number of animal 2017 estimate	21 145	1 320 294		21 145	1 783 158		Cattle population estimate for 2017 was obtained using cattle population in Mnisi for 2013 (n = 12 832) and annual growth rate (n = 13.3) to estimate for year 2014 - 2017. Prevalence rate of 3.1% was used.	[10,17]
3	Total number of animal involved at 3.1% prevalence rate of TB	656			656				
4	Mean cost of a cow in rural South Africa	12 000			12 000			Prevailing market price of adult Nguni cow at auction/rural South Africa (R10 500 - R12 000).	Market survey, 2017
5	Total cost of animals involved (100% loss)		7 872 000	5.96		7 872 000	4.41	Number of human cases was obtained using total human population estimate for 2015 (n = 80,000), annual growth rate (10.9% over 4 years; 2.75% per annum) and incidence rate of TB in humans for Mpumalannga (0.4%). Reduction in risk of transmission to other animals + prevention of 339 human cases are additional benefits not quantified in this analysis	[18-20]
6	Total cost of animals involved (50% loss)		3 936 000	2.98		3 936 000	2.21		
7	Total cost of animals involved (25% loss)		1 968 000	1.49		1 968 000	1.10		
8	Total cost of animals involved (10% loss)		787 200	0.60		787 200	0.44		
	Cost of partial rejection alone in Mnisi Community, Mpumalanga/annum								
9	Cost of lungs/kg (ZAR)	38			38				[21]
10	Average weight of lung in a standard cow (kg)	7.8	296.4		7.8	296.4			
11	Total costs for 656 lungs		194 438			194 438			[10]
12	Cost of liver/kg	35			35				
12	Average weight of liver in a standard cow (kg)	6.9	241.5		6.9	241.5			
14	Total costs for 656 livers		158 424			158 424			[10]
15	Total costs (lungs + livers)		352 862	0.27		352 862	0.20		[10]

Relative ratio of PMS to TST is 1.35, meaning that it is approximately 1.35 times cheaper to institute PMS with relatively equal benefit than to institute TST. ZAR = South African Rand.

Discussion

The experts confirmed that cattle are the most tested animals and the TST is most used test but agreed that the test is under-implemented and not effectively carried out. A review of the implementation strategies and reasons for non-compliance will need further evaluation. It will also be necessary to include all susceptible animals in such a surveillance programme. Furthermore, key challenges have been identified and efforts will need to be engaged to overcome these issues. Because outbreaks of other state-controlled diseases (foot and mouth disease, rabies, and brucellosis) divert attention from bTB surveillance, a comprehensive or integrated surveillance system that incorporates all the potential endemic diseases may need to be implemented. On the low level of compliance with second time visits by farmers, intensive awareness campaigns may achieve some degree of success. However, because farmers will prefer PMS, and experts will want a continuation of the TST, a blended approach combining these two surveillance systems may need to be assessed as no stakeholder can be ignored with regards to effective surveillance. It will be important for experts to also pay attention to gathering detailed field level data for future epidemiological evaluations. In the present survey, only 40% of the experts have verifiable prevalence data. It should be understood that the diptanks present excellent opportunity for the collation of such epidemiological data.

This study provides economic justification for the implementation of surveillance against bTB in the first instance, and showed evidence that PMS is cheaper than the TST.

It is approximately six times and four times more beneficial to perform the PMS and the TST surveillances respectively than to allow the spread of bTB in the Mnisi Community without any control. Mwacalimba, Mumba & Munyeme [22] have reported that taking into consideration only the monetary value of a cow at point of sale, there is a positive cost-benefit to the control of bTB. If a broader approach is considered such as the impact of TB on human health and tourism in TB affected wildlife, there is no doubt that costs associated with TB control are minimal compared to the benefits of eradicating TB [22]. In this analysis, even for 25% level of losses, it is beneficial to conduct surveillance against TB; however, lower level losses do not justify surveillance in this respect. This may partially explain why countries with low TB prevalences or disease-free status undertake meat inspection only as a cheap alternative for TB surveillance system [4].

It is agreed that this benefit cost analysis has certain limitations because it does not take into account the broader benefits of performing surveillance such as reducing zoonotic disease risk, human loss in quality of life and productivity when sick, loss in animal production, milk and meat yields, loss in tourism and conservation when wildlife species are affected. These may serve as additional reasons to justify surveillance in the Mnisi Community. Mpumalanga has a human TB incidence rate of 0.4% and this translates to 339 human infections in Mnisi Community. The control of TB in animals could potentially prevent a proportion of these human cases [18-20].

Conclusion

Finally, both models have their own merits and challenges. The PMS model would need increased manpower and transport resources while the TST has not been effective due to difficulty in implementation and low level of compliance. As the TST currently achieves low effectiveness in South Africa, merging the two surveillance systems remains a viable surveillance option. The most effective and cheapest way of controlling zoonotic diseases is to control it at the animal source, and this study may be used as a baseline for future studies to find more effective ways to control bTB in resource-poor or rural communities, and enhance the 'End TB' strategy [23].

Abbreviations

AHT: animal health technicians

bTB: Bovine Tuberculosis

DAFF: Department of Agriculture, Forestry and Fisheries, South Africa

ELISA: Enzyme-linked immunosorbent assay

IDSR: Integrated Disease Surveillance and Response System

IFN: Interferon

PMS: postmortem surveillance

PPD: purified protein derivative

TB: Tuberculosis

TST: tuberculin skin test.

Declarations

Ethical approval and consent to participate

The project was approved by the University of Pretoria Animal Ethics Committee (AEC), (certificate number v116-16) and Human Ethics Committee (certificate number 374/2016). All participants in the survey signed the consent form for participation.

Availability of data

All data associated with this work are available in the supplementary materials and tool online submitted with this manuscript. Furthermore, the full MSc (Tropical Animal Health) dissertation by Marange Rudo, from which this work was generated titled '*A comparison of perceptions of the tuberculin skin test and an incentive postmortem based surveillance system in the Mnisi community, Mpumalanga*', is available at the Department of Veterinary Tropical Diseases, Faculty of Veterinary Science, University of Pretoria and is permanently archived in the open access repository of the University of Pretoria (UPeTD).

Competing interest

The authors declare no conflict of interest that should stop the review or publication of the manuscript.

Funding

The student (RM) and the research was funded by the Belgian Development Cooperation Agency (RM) and National Research Foundation, South Africa (NRF) incentive funding (DM-L & FOF).

Authors' contributions

FOF and DM-L supervised the study. RM collected the field data. FOF & RM conducted the benefit-cost analysis. All authors contributed to the design of the study, writing of the manuscript and approved the submission.

Consent for publication

All author read and approved the manuscript for submission to and publication in the journal Cost Effectiveness and Resource Allocation. The authorities involve have no hesitation to publishing the findings from the study.

Acknowledgements

We acknowledge and appreciate the following people and institutions for their input and support: the Mnisi community, University of Pretoria projects facilitation team including Jacques van Rooyen, Ilana van Wyk, Jeanette Wentzel, and the environmental monitors who translated and facilitated engagements with the community. Special thanks to the Mpumalanga State Veterinary Services including Mr. Solly Mokone, the animal health controller and all the technicians for giving us access to their operational data and allowing us to conduct the study during their dipping sessions. Finally, we are grateful to the Belgian Development Cooperation Agency and NRF incentive funding for financing this research.

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Figures

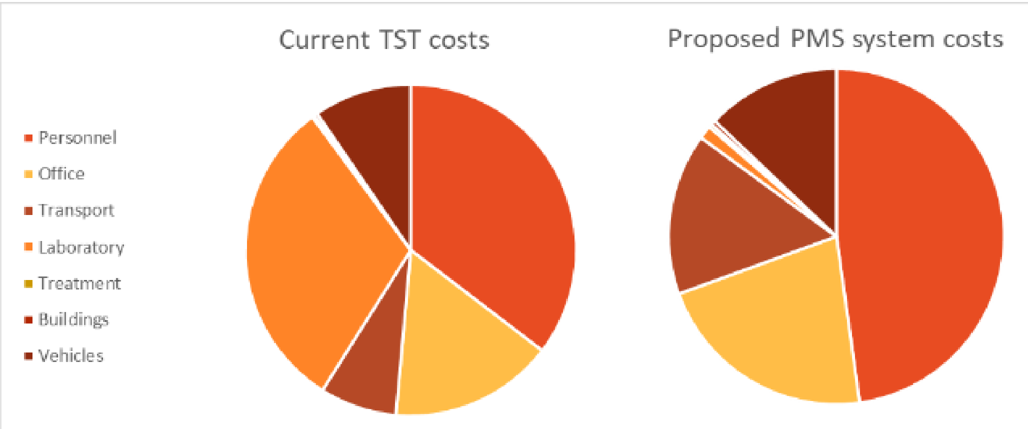

Figure 1

Comparison of current TST system costs versus proposed PMS system costs in Mnisi Community, Mpumalanga province as proportion of total IDSR program cost for animal disease surveillance, 2017 estimates

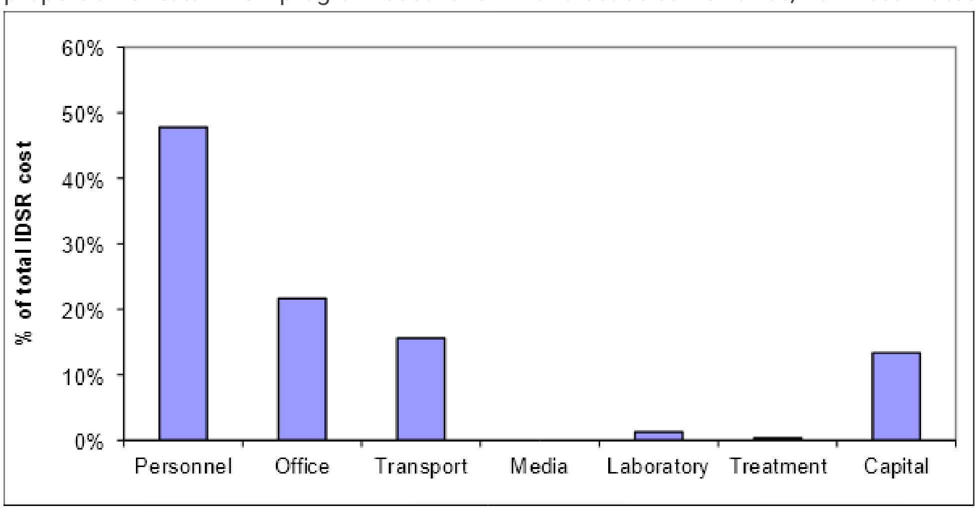

Figure 2

TST system costs in Mnisi Community, Mpumalanga province as proportion of total IDSR program cost for animal disease surveillance, 2017 estimates

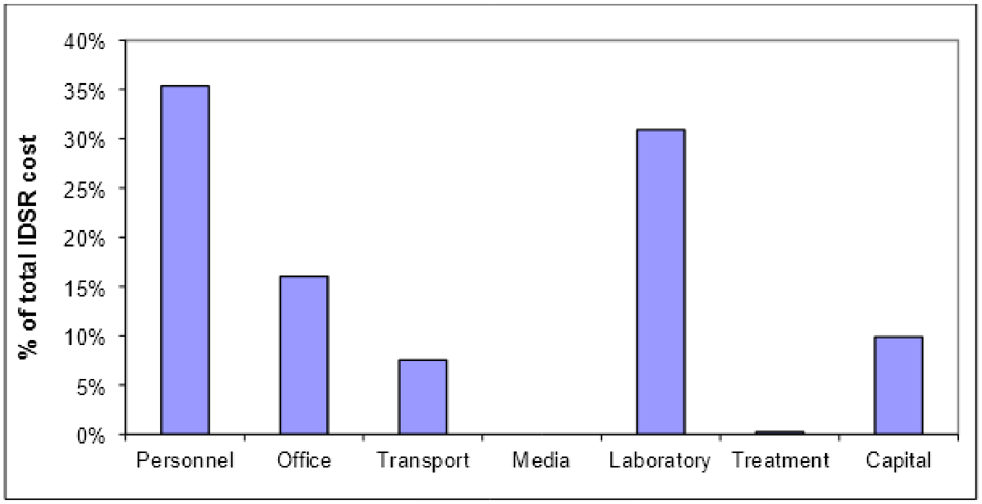

Figure 3

PMS system costs in Mnisi Community, Mpumalanga province as proportion of total IDSR program cost for animal disease surveillance, 2017 estimates

Supplementary Files

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- supplement8.xls