Sniff and tell: the feasibility of using bio-detection dogs as a mobile diagnostic intervention for asymptomatic malaria in sub-Saharan Africa.

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Abstract

Bio-detection dogs (BDDs) are used in some high-income countries as a diagnostic intervention, yet little is known about their potential in low/middle-income countries with limited diagnostic resources. This exploratory study investigated the opportunities and implications of deploying BDDs as a mobile diagnostic intervention to identify people with asymptomatic malaria, particularly at ports of entry, as an important step to malaria elimination in a population. A qualitative study design consisting of participant observation, five focus group discussions and informal conversations was employed in The Gambia (April-May 2017). A disciplined German shepherd companion dog (not trained as a BDD) was introduced to research participants and their perceptions recorded. Field-notes and discussions were transcribed, translated and analysed thematically. Most research participants viewed positively the possibility of using BDDs to detect malaria, with the major advantage of being non-invasive. Some concerns, however, were raised regarding safety and efficacy, as well as cultural issues around the place of dogs within human society. The Gambia is a rabies-endemic country, and unfamiliar dogs are not usually approached, with implications for how research participants perceived BDDs. Understanding such concerns and working with local people to address such issues must be part of any successful strategy to deploy BDDs in new settings. BDDs represent a potentially non-invasive diagnostic tool for the detection of asymptomatic or chronic malaria infections, particularly in areas with very low parasite rates. However, it is important to understand local concerns and work closely with communities to address those concerns. Wider deployment of BDDs will also require careful planning and sustained financial support.

Introduction

Bio-detection dogs (BDDs) are increasingly being deployed in high-income countries (HICs) as an efficient, reliable and mobile diagnostic intervention to detect volatile biomarkers contained in samples of human breath, skin and urine that are produced by particular diseases and health conditions. Recent trials have demonstrated that appropriately-trained dogs have the capacity to identify cancers of the lung, breast, bladder and prostate (Cornu *et al*., 2010; Ehmann *et al*., 2012; McCulloch, Turner & Broffman, 2012; Medical Detection Dogs n.d.; Willis *et al*., 2004; Taverna *et al*., 2014). Medical alert assistance dogs are also used on a one-to-one basis to provide advance warning of epileptic seizures and, for people living with type I diabetes, the onset of hypoglycaemia (Rooney, Morant & Guest, 2013). Very little is known, however, about the prospects for using BDDs in the Global South, where a lack of available, affordable and effective diagnostic technologies represents a major global health challenge (Petti *et al*., 2006; Okeke, 2006).

Malaria has been an exception to this diagnostic gap: the roll-out of Rapid Diagnostic Testing (RDTs) and Loop-mediated isothermal amplification (LAMP) kits have been major global health success stories, offering the possibility of effective diagnosis and treatment even in remote rural areas without laboratory facilities (Cook *et al*., 2015; World Health Organization, 2011). RDTs and LAMPs, however, are both invasive tests that require blood sampling, and are typically used for individuals suffering symptoms and actively seeking treatment. Asymptomatic individuals are unlikely to come forward for invasive testing, particularly in contexts where blood sampling may

be met with suspicion and resistance due to fears of 'blood theft' and 'blood-depletion' (Geissler & Pool, 2006; O'Neill *et al*., 2016; Fairhead, Leach & Small, 2006).

This is problematic for two reasons. First, parasitic infections of any density can pose serious health risks, particularly for infants and children in resource-poor settings, including morbidity, co-morbidity, mortality, and infection transmission (Chen *et al*., 2016). Second, the elimination of malaria requires that asymptomatic individuals, who constitute the 'human reservoir of infection' (Mwesigwa *et al*., 2015) are promptly identified and treated. BDDs may, therefore, offer a non-invasive opportunity to accurately screen for parasitaemia (in community settings and/or border crossings) by detecting malaria-specific volatiles among asymptomatic carriers (cf. Berna *et al*., 2015).

This article draws on data from qualitative research conducted in The Gambia during a proof-of-concept study to ascertain the ability of BDDs to identify asymptomatic malaria infections in children (Durham University News, 2016). Our premise is that the deployment of laboratory-designed interventions in the field requires an appreciation of the social and cultural contexts of deployment. As such, this exploratory study investigates human-canine relations in the Gambia as a basis for assessing the feasibility of future BDD deployment.

Materials and methods

Study site

This research was conducted in collaboration with the Medical Research Council Unit in The Gambia at the London School of Hygiene and Tropical Medicine (MRCG). The Gambia is a small low-income country in West Africa with an ethnically diverse, Muslim majority, population. The research sites included rural villages in the Upper River Region (URR) and urban settlements in the West Coast Region (WCR), (Figure 1). The qualitative research presented here forms part of a larger proof-of-concept study, to ascertain whether trained BDDs could detect volatiles from biological samples of malaria-infected children. The goal of the qualitative research component was to explore how Gambians might perceive the use of dogs as a diagnostic technology.

Malaria

At the end of the malaria transmission season in November 2016, the prevalence of asymptomatic malaria infection in 5-13 year old school children in the study area was 7.9% (46/585) as determined by microscopy. In rural Gambia clinical episodes of malaria are diagnosed using antigen-detecting rapid diagnostic tests or stained blood slides read using microscopes, both methods require a finger-prick sample of blood to be taken. Both RDTs and microscopy are sensitive methods for detecting clinical malaria where parasite densities are high (2000 or 5000 parasites/µL), they are less sensitive at low parasite densities (World Health Organization 2015; Satoguina *et al*., 2009). Moreover, strains of parasite have been detected that do not produce histidine rich protein 2, an antigen commonly used in RDTs, resulting in false negatives (Koita *et al*., 2012; Kumar *et al*., 2013).

Qualitative research

The qualitative research was conducted in April-May 2017. Initial ethnographic observations of human-dog interactions in public spaces were conducted, alongside a series of informal conversations on human-canine relations in local mosques, churches, pharmacies, health facilities, schools and local neighbourhoods (in both rural and urban sites). These informed the design of a semi-structured focus group discussion (FGD) guide to obtain more detailed information on attitudes towards the possibility of using BDDs for malaria diagnosis.

Five FGDs were then conducted in three rural villages (URR), with 18 female and 17 males participants (all over 18 years of age) from the three dominant ethnic backgrounds (Mandinka, Fula, and Serahuli); all but one were single-gender groups. Participants were recruited by MRCG field-workers in discussion with local *alkalos* (village heads). One limitation of this study is, therefore, that participants were not necessarily fully representative of other villagers, particularly those from minority ethnic backgrounds. As an exploratory study, however, this approach enabled us to quickly garner a reasonable spectrum of perspectives.

The focus groups proceeded as follows. After project sensitisation, participants were asked to discuss their experiences of, and attitudes towards, dogs in general before focussing more specifically on BDDs. The concept of BDDs was then raised by presenting a series of photographs showing working dogs in action, with the specific breeds (Springer Spaniels and Labradors) used by the UK-based

collaborating charity Medical Detection Dogs. A well-behaved adult German shepherd 'companion-dog' was introduced in three of the five focus groups in order to elicit post-exposure perceptions. The dog was dressed with a branded red coat worn by working BDDs in the UK, and walked using a harness and lead at all times.

The companion dog was also introduced to residents of three extended-family compounds, and to staff and pupils in a rural school serving primary and secondary-aged students. On one occasion the dog was led (by a handler) down a stationary line of research participants, mimicking the use of police dogs to identify criminal suspects, in order to observe people's reactions and provide a focus for further discussions. The current protocol of Medical Detection Dogs is identification using biological samples ('sample method'), but trialling a 'line-up method' was important to generate perceptions of BDDs as a *mobile* diagnostic technique. It is important to note that this German Shepherd companion-dog was the most appropriate substitute for a 'foreign' BDD at our disposal in The Gambia; all study participants were made aware that the dog was not a trained BDD.

All FGDs were convened by the lead author and were audio-recorded. MRCG Fieldworkers facilitated the discussions in Mandinka, Serahuli and Fula, providing real-time English translations. Other MRC staff checked the quality and consistency of translations. Detailed observational field notes were kept, alongside information from informal interviews and discussions. Analysis proceeded on the basis of Grounded Theory (Corbin & Strauss, 1990), whereby theoretical insights emerge from the data rather than being pre-imposed. All transcripts and field-notes were

read and re-read closely by two of the authors, to identify patterns and key themes for coding (performed manually in Word).

Informed consent was obtained verbally both from settlement leaders and individually from all study participants, in line with the Association of Social Anthropologists (2011) Ethical Guidelines. MRCG fieldworkers presented the project orally in the relevant languages (Mandinka, Fula, and Serahuli), ensuring that prospective research participants understood the purpose of the research, the procedures involved, and their right to withdraw at any point. The study was approved by the Gambian Government/MRC Unit Joint Ethics Committee on the 16th May 2017 (SCC1479v2) and by the Department of Biosciences Ethics Committee at Durham University.

[Figure 1]

Results

Canine-human relations in The Gambia

Free-roaming dogs are ubiquitous across The Gambia. So-called 'modern village dogs' (Coppinger & Coppinger, 2001; Boyko *et al*., 2009) – brown, short-haired, of small-medium build – can be seen wandering dusty roads and paths, perched outside market stalls, and panting underneath mango trees to escape the midday heat. Almost all dogs roam freely and fall into two broad categories: those owned by a family compound (and kept for security, company, and sometimes for hunting) and, as many locals described, a growing stray population. Stray dogs across rural

and urban areas were widely considered to be a nuisance. Focus group participants noted their unpredictability and potential to bite, prey on livestock, and even to exhume recently-buried bodies from cemeteries. Owned dogs could also bite, and some interviewees in the urban sites mentioned the high-profile case of the (then) President-Elect Adama Barrow's son being mauled to death by family-owned dogs in January 2017 (The Point, 2017; BBC News 2017). For these reasons there was a general (pre-exposure) consensus among research participants that they would not approach a stray dog and would not invite an unfamiliar dog to sniff them because, a consensus was, 'the likelihood of a bite is there.'

Introducing a mock-up BDD

Large audiences gathered to observe the mock-up BDD — an unfamiliar companion-dog being walked on a leash by foreigners — during our FGDs and compound visits. It is extremely rare to see a dog being walked on a leash, or otherwise constrained, in The Gambia. However, compound-owned dogs (used generally for security) are considered to be *under control* despite being free-roaming. The use of a leash and harness to manage the working dog therefore raised suspicions of some residents, who interpreted the dog as being *uncontrolled*: likely to bite if not firmly held by the handler and thus a threat to safety.

Despite initial wariness, however, most study participants found the actual dog much less intimidating than they had expected. One Serahuli woman, for example, summed up the feelings of others in her focus group when she said:

> Since the dog has been here with us it hasn't done anything and they are comfortable. For me seeing that, I have confidence that the dog will not do anything to me. I can get close to the dog with no problem.

It was important for many not to get *too close*, however, as this paper goes on to discuss.

The German Shepherd Dog was an unfamiliar and 'foreign' breed for study participants. This initially caused some scepticism; for example, one Serahuli man (pre-exposure) asserted, '*I would not want to be sniffed by any of these dogs because these are not the type of dogs we usually see here. They are only in the West*.' When introduced to the 'foreign' dog, however, there was a palpable shift in perception. As one Fula women put it, '*I will not refuse that [being sniffed], because our own dogs are different from this one because of training — our dogs are not trained*.'

Dogs and malaria diagnostics: perceptions of safety and efficacy

RDTs are the principal method for malaria diagnosis in the study sites. Most study participants believed RDTs to be a largely safe and effective diagnostic method but there were widespread concerns – and sometimes fears – about their invasive nature and the pain associated with using a blood lancet. One Mandinka mother, for instance, said, '*I am very scared of* [finger] *pricking: when my child is being pricked, I hold him close to my body because I feel it for the child*.' Another (Serahuli) woman recalled how, '*We were being pricked for blood samples, I did accept it but I was uncomfortable with the amount of blood being taken for the test. I could see the blood coming from the fingertip and that was not something I was comfortable with*.' In the light of this, most participants welcomed the possibility of a non-invasive diagnostic test. In the words of one Mandinka woman, '*If there is a dog that can sniff*

and know your problem or there is a needle that can prick you, which one are you going to pick? I'm going to pick the dog!'

In all five focus groups, however, concerns were expressed about safety and efficacy. Most prominent among these were anxieties about being bitten, particularly in a context where rabies remains endemic. One Fula male elder, for example, had serious reservations; his child had recently died shortly after being mauled by a dog and contracting 'mad dog disease' (suspected rabies). This, and similar accounts, led some to suggest the use of canine muzzles. Others did not object in principle but did not like the idea of a dog being *inside* (a health centre, for example); in The Gambia, dogs always stay outdoors. Some focus group participants also queried the *reliability* of BDDs compared with the more familiar RDTs, which were associated with health professionals and 'modern' clinics. Dogs and their handlers did not share this same professional status. Overall, participants wanted reassurance over both safety and capability, summed up eloquently by this Bambara mother:

> I would not trust the dog sniffing the child unless I was assured that the dog would not do anything but sniff. If that assurance and guarantee is given to me, then I can allow the dog to sniff my child. Based on that trust, that guarantee, and the fact that you have given me a strong word that the dog will not do anything but sniff and not bite — then I would accept.

Socio-cultural considerations

In addition to questions about efficacy and physical safety, social and religious concerns about BDDs were also widely raised. Interpretations of Islamic teachings

pertaining to impurity (Arabic, *najasa*) were often mobilised as an instruction for Muslims not to keep dogs, and some Muslim study participants considered it *haram* (forbidden) to touch a dog. Of particular concern was saliva: several participants explained that, according to Islamic teaching, cooking pots and utensils needed to be washed seven times if sniffed or licked by a dog. Such concerns were not exclusive to the Muslim majority population. A Christian priest declared that The Gambia (in general) was '*not a dog-loving community to the extreme that you have in the West*.' Although many Christians keep dogs for security and are Biblically-mandated to care for animals, he contrasted dog ownership in The Gambia with the '*lovey-dovey relationship that you have in England*.'

In practice, however, there was considerable ambivalence and negotiation, with practical concerns often overriding religious ones. In rural areas, for example, many Muslim participants kept dogs for guarding family compounds and hunting. Likewise, among the rising middle classes, dogs are seen as an effective (and perhaps more reliable) alternative to hiring a night watchman. Interestingly, a Mandinka *Imam* (religious authority) in the WCR maintained that, while dog *saliva* was *haram*, being *sniffed* by a BDD would not violate pre-prayer ablutions. In fact, he strongly supported their potential use for protecting people's health. A Serahuli *Imam* (WCR) corroborated this view, '*if you train a dog to sniff malaria, if that's the intention, you can do it*.'

Discussion

The findings presented in this paper give cause for optimism that BDDs could be an acceptable diagnostic technology even in populations in the Global South that are not normally regarded as 'dog friendly.' Despite some concerns, most study participants (men and women, from a range of religious and ethnic backgrounds) were favourably disposed to their potential use, at least in principle. Crucially, BDDs offered the possibility of a non-invasive malaria test, less painful than current diagnostic technologies.

These findings also underline the importance of understanding and addressing local concerns, many of which are rooted in very real and reasonable apprehensions, for example, about the risk of biting in a rabies-endemic country. Several focus-group participants proactively suggested possible solutions or mitigations, such as the ideas of equipping dogs with muzzles (although this would need careful trialling to ensure that the ability to detect volatiles would not be impaired). Religious injunctions also featured prominently among the concerns of Muslim participants in particular, but in practice there was substantial flexibility in interpretation, and many people took a pragmatic view of how to manage interactions with dogs without compromising their religious integrity. The *Imam* who distinguished 'sniffing' from the (forbidden) contact with saliva provides an excellent example of this. Context was also shown to be important in this study: *what kind* of dog and *where* (inside/outside) both mattered to different participants.

These specific findings may not be generalisable beyond the immediate context of The Gambia. They do, however, underline, the wider importance of

working with local people to understand and address their concerns before deploying a novel technology. In the case of BDDs, it is important to understand the wider context of canine-human relationships, and how these might be inflected by factors such as the appearance of the dog and handler, the location, the proximity and the most appropriate method (sample/line-up). The reaction of *Imams*, who took pragmatic views in the interests of protecting health, also underscores the value of working with local religious and other community leaders whose endorsement and input into accompanying awareness-raising initiatives can be crucial.

Conclusion

This study has provided a useful insight into a potentially important global health innovation: the use of BDDs as a mobile diagnostic method in LMICs, particularly at ports of entry in malaria-free countries. Specifically, it signposts issues likely to arise when BDDs are applied in the very different social landscapes of the Global South compared to current use in HIC settings, and highlights the importance of working *with* local communities and opinion leaders to identify and address their concerns.

As an exploratory study, our work has significant limitations: it was carried out over a relatively short time period (six weeks) among a non-representative population in pre-selected settlements in The Gambia. Research conducted over a larger geographical area, over a longer period of time, with a greater diversity of participants, might have identified other issues and concerns. It is also important to

recognise that social acceptability is only one of many hurdles that must be addressed for BDDs to be used at scale as diagnostic tools in the Global South. Even in high-income countries, their use remains limited, at least partly because of the substantial time and financial costs of breeding, training and looking after BDDs over the long-term.

Nonetheless, this study – and the accompanying proof-of-concept work – highlights the potential for using BDDs for diagnostic screening in LMIC settings. While the focus of this study has been specifically on malaria, the implications of possible BDD deployment are far-reaching in a continent where a chronic lack of diagnostic technology represents a major impediment to improving healthcare, particularly in the context of rising burdens of cancer and other non-communicable diseases (Livingstone, 2012; Stefan, 2015; Jedy-Agba *et al*., 2016). If that potential is to be realised, it is crucial that clinical/scientific research and development go hand-in-hand with social research to ensure that interventions are appropriately designed, in consultation with the intended beneficiaries.

Disclosure statements

Ethics approval and consent to participate

The study was approved by the Gambian Government/MRC Unit Joint Ethics Committee on the 16th May 2017 (SCC1479v2) and by the Department of Biosciences Ethics Committee at Durham University.

Consent for publication

MRCG fieldworkers obtained informed consent (including consent for publication) in the relevant languages (Mandinka, Fula, and Serahuli) of participants.

Competing interests

The authors declare that they have no competing interests.

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References

Association of Social Anthropologists of the UK and the Commonwealth (2011) Ethical guidelines for good research practice. https://www.theasa.org/downloads/ASA%20ethics%20guidelines%202011.pdf [Accessed 26 July 2018]

BBC News (2017) Gambia dog that killed President Barrow's son put down, 2 February. http://www.bbc.com/news/world-africa-38843251, [Accessed 30 April 2017].

Berna AZ, McCarthy JS, Wang RX, Saliba KJ, Bravo FG, Cassells J, Padovan B and Trowell SC (2015) Analysis of breath specimens for biomarkers of plasmodium falciparum infection. *Journal of Infectious Diseases* **212**, 1120–1128.

Boyko AR, Boyko RH, Boyko CM, Parker HG, Castelhano M, Corey L, Degenhardt JD, Auton A, Hedimbi M, Kityo R, Ostrander EA, Schoenebeck J, Todhunter RJ, Jones P and Bustamante CD (2009) Complex population structure in African village dogs and its implications for inferring dog domestication history. *Proceedings of the National Academy of Sciences* **106**, 13903–13908.

Chen I, Clarke SE, Gosling R, Hamainza B, Killeen G, Magill A, O'Meara W, Price RN and Riley EM (2016) Asymptomatic malaria: A chronic and debilitating infection that should be treated. *PLOS Medicine* **13**(1), e1001942.

Cook J, Aydin-Schmidt B, González IJ, Bell D, Edlund E, Nassor MH, Msellem, M, Ali A, Abass AK, Mårtensson A and Björkman A (2015) Loop-mediated isothermal amplification (LAMP) for point-of-care detection of asymptomatic low-density malaria parasite carriers in Zanzibar. *Malaria Journal* **14**(43). doi.org/10.1186/s12936-015-0573-y

Coppinger R and Coppinger L (2001) *Dogs: A startling new understanding of canine origin, behaviour & evolution*. Scribner, New York.

Corbin JM and Strauss A (1990) Grounded theory research: Procedures, canons, and evaluative criteria. *Qualitative Sociology* **13**(1), 3–21.

Cornu JN, Cancel-Tassin G, Ondet V, Girardet C and Cussenot O (2010) Olfactory detection of prostate cancer by dogs sniffing urine: A step forward in early diagnosis. *European Urology* **59**, 197–201.

Durham University News (2016) Could dogs be trained to detect malaria? https://www.dur.ac.uk/biosciences/newsandevents/?itemno=28148. [accessed 30 April 2017].

Ehmann R, Boedeker E, Friedrich U, Sagert J, Dippon J, Friedel G and Walles T (2012) Canine scent detection in the diagnosis of lung cancer: Revisiting a puzzling phenomenon. *European Respiratory Journal* **39**, 669–676.

Fairhead J, Leach M and Small M (2006) Where techno-science meets poverty: Medical research and the economy of blood in The Gambia, West Africa. *Social Science & Medicine* **63**, 1109–1120.

Geissler PW and Pool R (2006) Popular concerns about medical research project in sub-Saharan Africa – a critical voice in debates about medical research ethics. *Tropical Medicine and International Health* **2**, 975–982.

Jedy-Agba E, McCormack V, Adebamowo C and Dos-Santos-Silva I (2016) Stage at diagnosis of breast cancer in sub-Saharan Africa: A systematic review and meta-analysis. *Lancet Global Health* **4**, e923–e935.

Koita OA, Doumbo OK, Ouattara A, Tall LK, Konare A, Diakite M, Diallo M, Sagara I, Masinde GL, Doumbo SN, Dolo A, Tounkara A, Traoré I and Krogstad DJ (2012) False-Negative Rapid Diagnostic Tests for Malaria and Deletion of the Histidine-Rich Repeat Region of the hrp2 Gene. *The American Journal of Tropical Medicine and Hygiene* **86**(2), 194-8.

Kumar N, Pande V, Bhatt RM, Shah NK, Mishra N, Srivastava B, Valecha N, and Anvikar AR (2013) Genetic deletion of HRP2 and HRP3 in Indian Plasmodium falciparum population and false negative malaria rapid diagnostic test. *Acta Tropica* **125**(1), 119-21.

Livingstone J (2012) *Improvising medicine: An African oncology ward in an emerging cancer epidemic*. Duke University Press, Durham.

McCulloch M, Turner K and Broffman M (2012) Lung cancer detection by canine scent: will there be a lab in the lab? *European Respiratory Journal* **39**, 511–512.

Medical Detection Dogs (no date) Cancer and bio-detection dogs. https://www.medicaldetectiondogs.org.uk [accessed 30 April 2017]

Mwesigwa J, Okebe J, Affara M, Di Tanna GL, Nwakanma D, Janha O, Opondo K, Grietens KP, Achan J and d'Alessandro U (2015) On-going malaria transmission in The Gambia despite high coverage of control interventions: A nationwide cross-sectional survey. *Malaria Journal* **14**, 1–9.

Okeke IN (2006) Diagnostic insufficiency in Africa. *Clinical Infectious Diseases* **42**, 1501–1503.

O'Neill S, Dierickx S, Okebe J, Dabira E, Gryseels C, d'Alessandro U and Grietens KP (2016) The importance of blood is infinite: Conceptions of blood as life force, rumours and fear of trial participation in a Fulani village in rural Gambia. *PLoS ONE* **11**, e0160464.

Petti CA, Polage CR, Quinn TC, Ronald AR and Sande MA (2006) Laboratory medicine in Africa: A barrier to effective health care. *Clinical Infectious Diseases* **42**, 377–382.

Rooney NJ, Morant S and Guest C (2013) Investigation into the value of trained glycaemia alert dogs to clients with type I diabetes. *PLoS One* **8**(8), e69921.

Satoguina J, Walther B, Drakeley C, Nwakanma D, Oriero EC, Correa S, Corran P, Conway DJ and Walther M (2009) Comparison of surveillance methods applied to a situation of low malaria prevalence at rural sites in the Gambia and Guinea Bissau. *Malaria Journal* **8**(274), e274.

Stefan DC (2015) Cancer care in Africa: An overview of resources. *Journal of Global Oncology* **1**, 30–6.

Taverna G, Tidu L, Grizzi F, Torri V, Mandressi A, Sardella P, La Torre G, Cocciolone G, Sevesso M, Giusti G, Hurle R, Santoro A and Graziotti P (2014) Olfactory System of Highly Trained Dogs Detects Prostate Cancer in Urine Samples. *Journal of Urology* **193**, 1382–1387.

The Point (2017) President-elect Barrow's son dies from dog bite, 17 January. http://thepoint.gm/africa/gambia/article/president-elect-barrows-son-dies-from-dog-bite.
[Accessed 30 April 2017].

Willis CM, Church SM, Guest CM, Cook WA, McCarthy N, Bransbury AJ, Church MRT and Church JCT (2004) Olfactory detection of human bladder cancer by dogs: proof of principle study. *British Medical Journal* **329**(712). doi.org/10.1136/bmj.329.7468.712

World Health Organization (2011) Universal access to malaria diagnostic testing: An operational manual. Geneva. http://apps.who.int/iris/bitstream/handle/10665/44657/9789241502092_eng.pdf;jsessionid=E07DB28A7543179753DD9190F2778772?sequence=1
[Accessed 26 July 2018]

World Health Organization (2015) Malaria rapid diagnostic test performance. Results of WHO product testing of malaria RDTs: round 6 (2014-2015). Geneva. http://www.who.int/malaria/areas/diagnosis/rapid-diagnostic-tests/product-testing-round6/en/
[Accessed 3 December 2018]