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Diagnostics for optimised dengue surveillance: Investigating user experience and requirements

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3	1	Diagnostics for optimised dengue surveillance: Investigating user experience and
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ABSTRACT Objectives Effective, real-time surveillance of dengue may provide early-warning of outbreaks and support targeted disease-control intervention but requires widespread accurate diagnosis and timely case-reporting. This study aimed to identify requirements for new diagnostics

29 which will enhance dengue surveillance.

30 Methods

Data were collected from 19 users of diagnostic technology who work across the Thai
dengue surveillance system. Contextual knowledge, experience and needs were explored in
focus groups. Discussions were translated, transcribed, analysed thematically and mapped
to Consolidated Framework for Implementation Research domains.

35 Results

Participants expressed a need for rapid, accurate, serotype-specific tests which can be
operated easily by non-expert users without laboratory equipment. They supported
integration of diagnostics with surveillance systems and felt this would increase the quantity
and speed of case-reporting as well as provide healthcare professionals with up-to-date
information about the number of cases locally, thereby aiding interpretation of test results.
Concerns included those relating to data security and the cost of tests.
Conclusions

43 Engagement to understand prospective user experience and requirements can improve

- 44 relevance and uptake of new technology, leading to system efficiencies. The present study
- 45 highlights specific needs for accurate, serotype-specific, remote-connected diagnostics

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2 3 4	46	which are integrated with surveillance systems and support dengue case-reporting at the
5 6 7	47	point-of-care.
8 9 10	48	KEYWORDS
11	49	Dengue
12 13	50	Diagnostics
14 15	51	Focus group
16 17	52	Surveillance
18 19	53	Surveillance User requirements
20 21	54	
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STRENGTHS AND LIMITATIONS OF THIS STUDY

Strengths:

First study to specifically investigate user requirements for diagnostics which support

dengue surveillance.

Included a wide range of diagnostic technology users in Thailand , including those who

operate tests and those undertake downstream analysis and usage of data.

Challenges are identified and key desirable features for portable, serotype-specific, remote-

connected diagnostic devices are described.

Limitations:

- Only included participants working within one national surveillance system and excluded
- patients and the general public who also play pivotal roles as users.

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53 54 55 56 57 58 59 60	lies

68 INTRODUCTION

Dengue is a mosquito-borne neglected tropical disease which affects 100-400 million individuals annually and is a significant cause of morbidity and mortality among adults and children. It is caused by four dengue virus serotypes (DENV1-4) which co-circulate in many regions.[1] Dengue causes a diverse clinical syndrome ranging from asymptomatic or mild, self-limiting illness to dengue haemorrhagic fever, dengue shock and death.[2] 'Secondary dengue infection', which occurs when an individual is infected for a second (or subsequent) time by a different serotype to their earlier 'primary infection', is most likely to result in severe disease.[3]

A diagnosis can be suspected based on clinical features and routinely available laboratory data but should be confirmed using a diagnostic test.[4] Reverse-transcriptase polymerase chain reaction (RT-PCR) assays are considered the modern reference standard.[5] RT-PCR requires significant laboratory infrastructure and a skilled workforce, resulting in its limited use in rural and remote locations.[6] Rapid diagnostic tests (RDTs) are low-cost and simple to use but have varying sensitivity compared to RT-PCR (40% to >90%) and cannot currently determine the infecting serotype.[7]

Outbreaks of dengue are typically seasonal with the number of cases and proportion causing severe disease being highly variable between years. Shifts in the predominant circulating serotype may lead to more severe outbreaks.[8] In 'passive surveillance', cases are identified via the routine assessment of unwell patients at healthcare facilities and are notified to a central surveillance authority. This relies on availability and utilisation of accurate diagnostic tests and effective, timely communication of results alongside clinicallyderived metadata. Passive surveillance may be augmented at 'sentinel sites', with samples Page 9 of 31

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91	undergoing additional serotype-specific testing.[9], [10] Effective implementation of such
92	systems with real-time data transfer may provide early outbreak warning.[9], [10], [11], [12]
93	However, common weaknesses include poor access to diagnostic testing and delayed or
94	incomplete reporting.[9], [13] In Thailand, there is mandatory reporting of clinical or RDT-
95	confirmed cases to regional surveillance authorities by healthcare facilities.
96	Several advances in diagnostic technology represent opportunity to enhanced dengue
97	surveillance.[14] Novel molecular techniques such as reverse-transcriptase loop-mediated
98	isothermal amplification (RT-LAMP) may lead to high-sensitivity portable diagnostic devices
99	for detecting and serotyping infections.[15], [16] Mobile phone and global positioning
100	system (GPS) technologies may be integrated to automate case notification.[12], [17], [18]
101	In the context of dengue surveillance, 'users' of technology include those involved in the
102	operation and interpretation of diagnostic devices, and/or the use of data generated to
103	make decisions about management of individual patients and population level surveillance
104	or disease control.[19] The professional occupation of individuals undertaking these
105	activities varies between country and healthcare setting, but may include public health
106	practitioners, surveillance officials, doctors, nurses and laboratory scientists. Patients and
107	the general public also play pivotal roles as users. Previous studies evaluating the
108	implementation of RDTs have identified potential barriers from the perspective of users.
109	These include unreliable supply chains, user training requirements, practical limitations in
110	operating devices, difficulties interpreting and recording results, distrust of results, and a
111	lack of impact on clinical decision making.[20], [21], [22], [23], [24] Beyond infectious
112	disease diagnosis and surveillance contexts, there is frequent non-adoption of health
113	technology, including in rural and remote settings.[19], [25], [26] It is crucial that technology

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114	is developed and evaluated in collaboration with intended users. Engagement throughout
115	the design process likely results in optimised solutions and maximised chances of
116	technology adoption.[27] The Consolidated Framework for Implementation Research (CFIR)
117	provides a set of domains which can be used to systematically assess barriers and
118	facilitators to implementing health intervention. These include the intervention itself and
119	how it may be adapted, the setting, the processes, and individuals involved, [28]
120	This study engaged users of diagnostic technology working across the Thai dengue
120	This study engaged users of diagnostic technology working across the that deligue
121	surveillance system. It explored their contextual knowledge, experience and needs, with
122	the aim of determining requirements for new devices and their implementation in systems
123	of dengue surveillance.
124	
125	METHODS
126	Setting
127	This qualitative study was conducted during July 2022 at four institutions in Thailand: The
128	Division of Vector Borne Diseases, Department of Disease Control at the Ministry of Public
129	Health is the national authority responsible for surveillance of dengue and strategies for
130	dengue control. The Hospital for Tropical Diseases is a tertiary care hospital specialised in
131	tropical diseases including dengue. Khon Kaen hospital is a public hospital which provides
132	inpatient and outpatient care for rural patients. The Dengue Haemorrhagic Fever Research
133	Unit at Mahidol University, Bangkok is an academic centre with a multidisciplinary dengue
134	research portfolio.
135	Participants

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3 4	136	A purposive sample was taken to ensure inclusion of participants with a range of experience
5 6 7	137	across dengue surveillance in Thailand. This included public health practitioners,
8 9	138	surveillance officials, doctors, nurses, laboratory scientists and dengue researchers.
10 11 12 13	139	Data collection
14 15 16	140	Data were collected during four focus group discussions, each including between four and
17 18	141	seven participants. These were facilitated by two researchers and were conducted either in
19 20	142	English or Thai language, depending on participant preference. Discussion was facilitated
21 22 23	143	using a topic guide, developed in advance based on literature review and expert's opinion
24 25	144	regarding knowledge and innovations in dengue diagnosis and surveillance (Table 1). This
26 27 28	145	was reviewed and revised iteratively during and between sessions, to ensure that emerging
29 30	146	themes could be identified, explored further and triangulated within and between groups of
31 32 33	147	participants. Focus groups were audio-recorded and written notes were taken. Recordings
34 35	148	were transcribed and Thai was translated to English language.
36 37 38 39	149	
40 41 42	150	<table 1="" here=""></table>
43 44 45	151	
46 47 48	152	Data Analysis
49 50 51	153	A thematic analysis was undertaken.[29] Transcripts from each focus group were annotated
51 52 53	154	and analysed by two researchers who assigned codes independently and then discussed and
54 55	155	aggregated them into themes. A deductive approach was used, with themes mapped to
56 57 58 59 60	156	CFIR domains.[28], [30] 'Current practices and challenges' and 'requirements for new

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diagnostics in surveillance' were overarching themes agreed a priori, as they were central to the aim of the study. **Ethical considerations** Potential participants received verbal and written information about the proposed study purpose and its procedures. This study received ethical approval from Mahidol University Faculty of Tropical Medicine Research Ethics Committee (MUTM-2022-031-01) RESULTS Identified themes mapped to the CFIR (Figure 1) demonstrate barriers across all parts of the system including the poor fit between current technologies and adopting context. Features likely to address these barriers (Figure 2) are also identified, providing viable design and implementation approaches. These are further described and supported by selected quotations from participants below. **Current practices and challenges Diagnosis of dengue:** Participants described how individuals with dengue may seek healthcare at different types of healthcare facility, including primary health centres, district hospitals, regional hospitals, referral hospitals, pharmacies or private clinics, with each type having different clinical workforce and diagnostic test availability. There is a lack of diagnostic testing in many rural and remote settings.

2 3		
4 5	177	"It depends on the level of [healthcare facility], if located in a very remote area, they cannot
6 7 8	178	do a blood test."
9 10 11	179	- Participant 6, Laboratory Scientist. Focus group 2.
12 13 14	180	
15 16	181	Senior doctors described frequently diagnosing dengue based on clinical features and many
17 18 19	182	said they often did not use a diagnostic test.
20 21 22	183	
23 24 25	184	"I think the senior doctors like me are very used to following the clinical, but I think the new
26 27 28	185	generation of doctors are more likely to use the [RDT]."
29 30 31	186	 Participant 13, Doctor (Paediatrics). Focus group 3.
32 33 34	187	
35 36 37	188	Cited reasons for not testing included a high degree of confidence in clinical diagnoses,
38 39	189	potentially inaccurate tests, and resource wasting. Some reported only using tests in
40 41 42	190	atypical cases or outside dengue season.
43 44 45	191	When tests are used, RDTs are operated at laboratories or 'mini laboratories' (non-clinical
46 47	192	areas attached to smaller healthcare facilities), by a laboratory scientist, or sometimes at
48 49 50	193	the point-of-care by a nurse. RT-PCR is rarely used because samples (or patients
51 52 53	194	themselves) must be transported to specialist laboratories and results may be delayed.
54 55	195	Case reporting and information transfer: Participants described a system of passive disease
56 57 58	196	surveillance requiring multiple stages of information transfer. Typically, diagnosed cases of
59 60	197	dengue are communicated to an individual with responsibility for disease reporting at a

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2 3 4	198	health facility. Information is then transferred sequentially to local, regional and national
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	199	levels of the surveillance system (figure 3).[31]
	200	
	201	<figure 3="" here=""></figure>
	202	
	203	This information transfer could be incomplete or delayed, potentially by up to 4 weeks, due
	204	to laborious data input procedures, frequent duplication of tasks and lack of time- and
	205	resource- allocation for these activities.
25 26 27 28	206	
29 30 31 32 33 34 35 36 37 38 39 40 41 42	207	"Oh I'm really sad to tell you, not only do we have an underdiagnosis situation, but we
	208	have an underreporting situation also."
	209	- Participant 17, Senior Surveillance Official. Focus group 4.
	210	
	211	"One of the reasons they don't report is they have to sit down and key in the result."
43 44 45	212	- Participant 18, Surveillance Official. Focus group 4.
46 47 48	213	
49 50 51	214	Some participants also described a parallel sentinel site surveillance system, with samples
52 53	215	undergoing serotype-specific testing at a central location. However, only low numbers of
54 55 56	216	cases are included, these are not recruited systematically, and batch-testing results in
57 58 59 60	217	availability of serotype data being delayed.

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3 4	218	Use of surveillance data: When participants were asked about the benefits of case-
5 6 7	219	reporting, responses varied according to professional occupation. Doctors, nurses and
8 9	220	laboratory scientists did not identify benefits from this activity and were unaware of
10 11 12	221	downstream processes . They rarely received epidemiological information or warning about
13 14	222	outbreaks as a result participation in surveillance.
15 16 17	223	
18 19 20 21	224	"No one tells us, we just know when a large number of patients is coming!"
22 23	225	- Participant 13, Doctor (Paediatrics). Focus group 3.
24 25 26 27	226	
28 29 30	227	Public health practitioners and surveillance officials explained how national and regional
30 31 32	228	data is collated into reports but agreed that information could be disseminated more rapidly
33 34	229	and used more efficiently locally.
35 36 37 38	230	
39 40 41	231	Requirements for new diagnostics in surveillance
42 43 44	232	Use setting and operator skillset: Participants stated that new devices for the diagnosis of
45 46	233	dengue should be usable in a wide range of settings, including at the point-of-care (inpatient
47 48 49	234	and outpatient) and in laboratories and 'mini laboratories'. There was a preference for
50 51	235	analysing a small volume (up to 4 drops, ~140uL) of capillary blood, obtainable by finger-
52 53 54	236	prick and transferred directly into the device.
55 56 57 58	237	
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3 4	238	"If we use it in outpatients where there are many patients, obtaining blood from the
5 6 7	239	fingertip would be suitable"
8 9 10	240	- Participant 14, Nurse (Inpatient). Focus group 3.
11 12 13	241	
14 15 16	242	There was a strong desire for minimal sample processing prior to analysis (i.e.
17 18 10	243	centrifugation, pipetting, mixing or addition of reagents). This was frequently explained by
19 20 21	244	reference to currently available RDTs, which are simple to use.
22 23 24	245	
25 26 27 28	246	"Nurses are not using pipette. If that's needed, it needs to be in the lab."
29 30 31	247	- Participant 7, Nurse Assistant (Outpatients). Focus group 2.
32 33 34	248	
35 36 37	249	"We have to try to mimic the [RDTs]"
38 39 40	250	- Participant 3, Dengue Researcher. Focus group 1.
41 42 43	251	
44 45 46	252	Diagnostic targets: Many participants stated that new diagnostic devices should have the
47 48	253	ability to serotype infections. Public health practitioners, surveillance officials and several
49 50 51	254	dengue researchers had particularly strong desires for this, noting that it has not been
52 53 54	255	achieved by currently available RDTs.
55 56 57 58 59 60	256	

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3 4	257	"If we can get the serotype in real-time of course it will make our control measures more
5 6 7	258	effective."
8 9 10 11	259	- Participant 19, Surveillance Official. Focus group 4.
12 13	260	
14 15 16 17 18	261	Doctors and nurses could also understand this potential surveillance benefit but stated that
	262	serotypes are of little consequence for individual patient management.
19 20 21	263	
22 23 24	264	Assay performance characteristics and implications for clinical and public health
25 26	265	management of dengue: Most participants cited 'accuracy' as an important characteristic.
27 28 29 30 31 32 33 34	266	They recognised that existing dengue tests were sometimes insensitive which could affect
	267	patient management as well as surveillance. Insensitive tests which give falsely negative
	268	results may lead missed diagnoses of dengue, with further testing and treatments for other
35 36 27	269	causes (for example bacterial infections) being initiated or continued unnecessarily.
37 38 39 40	270	
41 42 43	271	"If the doctors see that the test is negative, [they] might diagnose something else and treat
44 45	272	something else, like bacterial infection [this] might harm the patient."
46 47 48 49 50 51 52	273	- Participant 10, Doctor (Internal Medicine). Focus group 4.
	274	
53 54	275	They suggested that new devices should have at least the same sensitivity as currently
55 56 57 58 59 60	276	available RDTs.

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3 4	277	Participants also recognised that non-specific tests could lead to alternative diagnoses being
5 6 7	278	missed and discontinuation of important treatments (for example antibiotics).
8 9 10	279	
11 12 13	280	<i>"If it has false positive it may lead to mistreatment of other diseases"</i>
14 15 16	281	- Participant 16, Doctor (Internal Medicine). Focus group 3.
17 18 19 20	282	
20 21 22 23	283	"This means it's not dengue but something else. Yes definitely, this delays the treatment.
24 25 26	284	Yes it's going to be a problem."
27 28 29	285	- Participant 10, Doctor (Internal Medicine). Focus group 4.
30 31 32	286	
32 33 34	287	They caveated this by suggesting that users would become familiar with the performance of
35 36 37	288	any new test, and would interpret results accordingly. They also described how clinical and
38 39	289	epidemiological context are considered, when interpreting dengue test results.
40 41 42 43	290	
43 44 45	291	"We use it along with [routine laboratory data]. If [the test] is negative, but the case is likely
46 47 48	292	to be dengue, we still have [routine laboratory data] to follow-up the patient"
49 50 51	293	- Participant 16, Doctor (Internal Medicine). Focus group 3.
52 53 54	294	
55 56 57	295	"If the local prevalence of the infection is high, then the test-negative will not ensure that the
58 59 60	296	patient has no dengue infection. But if the patient is in a without dengue area, we will have

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1 2		
3 4	297	high confidence that this patient does not have dengue infection. It will depend on the
5 6 7	298	prevalence at the time and in the local area."
8 9 10	299	- Participant 16, Doctor (Internal Medicine). Focus group 3.
11 12 13	300	
14 15 16	301	Many participants also cited 'fast result' as an important characteristic. This was particularly
17 18	302	important for nurses and laboratory scientists who are frequent operators of RDTs. They
19 20 21	303	suggested target sample-to-result time should be below one hour (and ideally below 15-20
22 23 24	304	minutes).
25 26	305	The 'ability to quantify virus' was not considered an important characteristic, either for
27 28 29	306	clinical or surveillance purposes. However, some participants acknowledged potential utility
30 31	307	in clinical research, for example in trials of antiviral mediations.
32 33 34	308	
35 36 37	309	Connectivity and metadata: Participants recommended that diagnostic devices should
38 39	310	have a simple way of displaying results to users with low chance of misinterpretation. They
40 41 42	311	also stated that results should be recorded permanently on a patient's record. This could be
43 44	312	achieved by integrating devices with electronic patient records and/or laboratory
45 46 47	313	information systems, or by allowing results to be printed.
48 49 50	314	There was agreement among all participants that integrating diagnostic devices with
51 52	315	surveillance systems could be helpful, and that receiving serotype data would support
53 54 55	316	surveillance efforts. Many suggested that it would reduce requirements for informal
56 57	317	communication, paper records, data input and duplication of work at several levels of the
58 59 60	318	surveillance system, hence improving case reporting. Public health practitioners and
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3 4 5	319	surveillance officials detailed which metadata should be reported routinely alongside the
6 7	320	test results (Table 2). They also felt that optional reporting of pertinent clinical details could
8 9	321	be useful (for example details of particularly severe or atypical cases which may warrant
10 11	322	further investigation).
12 13 14 15	323	
16 17 18	324	<table 2="" here=""></table>
19 20 21	325	
22 23 24	326	As well as performing automated case notification ('upwards data transfer'), participants
25 26	327	suggested that a new diagnostic device could also receive and display epidemiological data
27 28 29	328	to the user ('downwards data transfer'). They expressed their desires for up-to-date
30 31 32 33 34	329	information about the numbers and severity of dengue cases in their area and agreed that
	330	devices which provide early warning of dengue outbreaks would be useful.
35 36 37	331	
38 39 40	332	"If we know the information about the outbreak of dengue cases in the surrounding area, we
40 41 42 43 44 45 46	333	will be more aware of the possibility of more severe cases coming to the hospital"
	334	- Participant 13, Doctor (Paediatrics). Focus group 3.
47 48 49	335	
50 51 52	336	Some explained how this knowledge could be used to assist in the interpretation of the
53 54	337	dengue test itself.
55 56 57 58 59 60	338	

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3 4 5	339	"When patients present with fever during the outbreak season the clinician usually ask
5 6 7	340	where they come from. If we know that they come from an outbreak area, it increases the
8 9 10	341	possibility that the case may be dengue"
11 12	342	- Participant 13, Doctor (Paediatrics). Focus group 3.
13 14 15	343	
16 17 18	344	However, some participants had concerns relating to data security, particularly if devices
19 20	345	could receive, store or display potentially sensitive information about other cases in the
21 22 23	346	region (for example their location).
24 25 26	347	
27 28 29	348	"Someone can think about stigmatisation. OK so this family has dengue and someone can
30 31	349	think that they are spreading dengue to the village, or something like that."
32 33 34	350	- Participant 10, Doctor (Internal Medicine). Focus group 2.
35 36 37 38	351	
39 40	352	Cost: Participants emphasised the importance of cost when considering the potential
41 42 43	353	introduction of new diagnostic devices in Thailand. Usually, diagnostic testing is paid for by
44 45 46	354	government insurance coverage, private insurance, or personal funds. Many participants
47 48	355	considered a conceptual difference between testing which is undertaken for individual
49 50 51	356	patient benefit (i.e. for diagnostic purposes) and that which is undertaken for potential
52 53	357	collective population benefit (i.e. for surveillance), and felt that using personal funds to pay
54 55 56	358	for the latter would be unfair.
57 58 59 60	359	

60	DISCUSSION
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> Participants in this study identified the need and potential value of new tests for dengue which are accurate, rapid, low cost and can be operated easily by non-expert users outside laboratory settings, including in remote and rural areas. They supported integration of diagnostic devices with surveillance systems to increase quantity and speed of case-notification. These requirements align with The World Health Organization (WHO) Special Program for Research and Training in Tropical Diseases 'ASSURED' criteria for diagnostics, and subsequent publications supporting real-time connectivity ('REASSURED' characteristics). [32], [33], [34] Tests which can serotype may be important for surveillance but are less likely to benefit individual patients. As well as 'upwards data transfer' (such that cases are notified by devices to the surveillance authority), it was felt that 'downwards data transfer' (from the surveillance system to each diagnostic device) would also be useful. This could provide healthcare professionals with up-to-date information about local dengue cases, assisting them in the interpretation of individual test results and potentially warning them of outbreaks. Cautions relating to this overall approach included data security and the potential cost when compared to currently available diagnostic tests. Previous studies have explored healthcare workers' and community members' perceptions of new diagnostic devices for tropical infections, particularly those intended to be used at the point-of-care. Diggle et al investigated malaria RDTs in Northern Kenya and found significant knowledge gaps, misconceptions and evidence of low uptake. Reasons included perceptions that testing was unnecessary, distrust of results, fear that devices might also test for other, potentially stigmatised conditions, and cost. However, RDTs were noted for their ease of use and portability.[21] Rasti et al investigated Southwestern Ugandan

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healthcare workers who described point-of-care tests improving diagnosis and clinical 383 decision making in under-resourced areas. However, they also reported experiencing 384 385 inaccurate results and a need to interpret and corroborate results with other clinical information.[23] Boadu et al identified influencers of malaria RDT implementation among 386 387 primary healthcare providers in central Ghana. These included healthcare delivery constraints, provider perceptions and social dynamics of care delivery. [20] A scoping review 388 389 of the use of mobile phones in the prevention and control of arboviral infections identified 390 six studies where mobile phone technology formed part of a diagnostic workflow, and 25 391 studies where mobile telephones were used in various surveillance activities.[35] Cited 392 benefits were a 'reduction in error of transcribed data', 'rapid data transfer', and 'good completeness in terms of more dengue case reporting', which are highly relatable to the 393 present study's findings.[35] 394 This study is the first to specifically investigate user requirements for diagnostic devices that 395 396 would optimise dengue surveillance. It collected data from a wide range of diagnostic

technology users, including those who make decisions to test, those with hands-on
 experience of operating tests, and those who are involved in downstream analysis and
 usage of data. Broad inclusion appears to have been important because user requirements
 sometimes varied between occupational groups. Innovation in technology should account

401 for this and may need to balance priorities of different users.

402 Limitations of this study include its restriction to one country, which could mean that 403 findings are geographically specific and are not fully transferrable to other settings. 404 However, many of the practices and challenges described appear similar to those 405 experienced in other Southeast Asian nations[9] and more widely.[13] Additionally, it did

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406	not include patients or members of the general public, who are important users of
407	diagnostic technology. In Thailand, there has been rapid increase in the use of mobile phone
408	technology, including for storage and sharing of personal health records.[36], [37] Results
409	from the present study highlight further need to engage this group, particularly around the
410	importance of data security.
411	Dengue is a major public health concern across tropical regions. Accurate, serotype-specific,
412	remote-connected diagnostic devices which can be used in a diverse range of settings would
413	enhance surveillance and could support real-time outbreak risk-assessment and warning.
414	These should be developed in collaboration with a range of prospective technology users.
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419	
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425	Antimicrobial Resistance at Imperial College London in partnership with the UK Health
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427	Cambridge and the University of Warwick. The views expressed in this publication are those

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3 4	428	of the authors and not necessarily those of the NHS, the National Institute for Health					
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13 14 15	432	Liverpool.					
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21 22 23	435						
24 25 26 27	436	COMPETING INTERESTS					
28 29 30	437	All authors declare that there are no competing interests					
31 32 33	438						
34 35	439	AUTHOR CONTRIBUTIONS					
36 37 38	440	PArkell, SK, AS, DM, RA and SL designed the study. PArkell, SK and SL collected data. PArkell					
39 40 41	441	and SK analysed data and drafted the manuscript. JR, PG, PM, PAvirutnan and AH were					
42 43	442	awarded funding to collaborate and undertake a programme of dengue diagnostics					
44 45 46	443	development which includes this qualitative work. All authors critically appraised the					
47 48	444	manuscript and agreed to its submission for publication. PA is responsible for the overall					
49 50 51	445	content. PA is the corresponding author and attests that all listed authors meet authorship					
52 53	446	criteria and that no others meeting the criteria have been omitted.					
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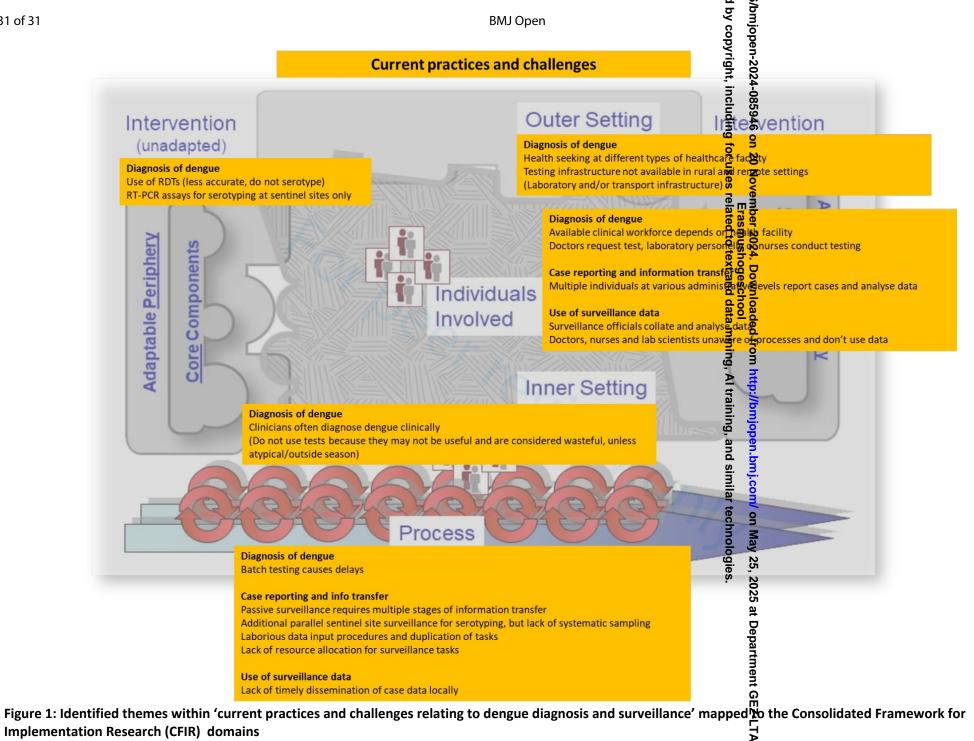
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Α.	Contextual understanding and needs assessment.
-	How is dengue surveillance done, at your workplace (and more broadly)?
-	Where do patients present to with symptoms of dengue and how do they get diag
-	If tests are not always done, why do you think this is?
-	Where / how should cases of dengue get reported, to surveillance?
-	If positive results are not always reported, why do you think this is?
-	How are surveillance data used?
в.	Requirements for new diagnostic devices: The assay.
-	Where does diagnostic testing usually occur, and what laboratory equipment is av there (if any)?
-	Who typically operates diagnostic devices, and what sample preparation / analysi do they have (if any)?
-	What do you think would be the preferred sample type and sample volume, that into any new diagnostic device?
-	What do you think would be the preferred (and maximum) time from sample to r (i.e. test duration), of any new diagnostic device?
-	What do you think the preferred (and minimum) sensitivity and specificity, of any diagnostic device?
-	Is knowing the dengue serotype important?
-	Is knowing the quantity of dengue (level of 'viraemia') in a patient's sample impor
C.	Requirements for new diagnostic devices: Remote connectivity and reporting.
-	How are results from diagnostic tests generally reported, and where are they stor
-	If a new diagnostic device could be remote-connected, where should results be reto?
-	Which information about cases would be most useful to report alongside test rest enhance dengue surveillance?
-	Would it be useful if a new diagnostic device could receive and display real-time information about local dengue incidence to the user (as well as transmitting data case-reporting)?

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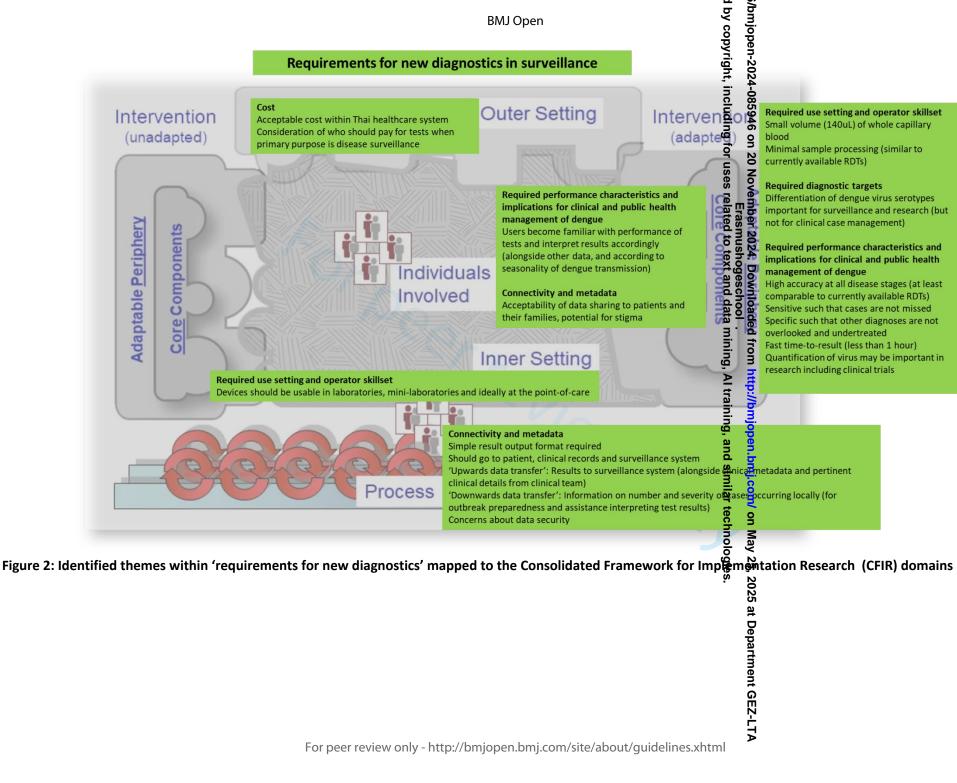
3 4	585	Table 2: Metadata which could be reported automatically from diagnostic devices to the surveillance authority ('upwards data transfer') and from surveillance to the diagnostic device ('downwards data transfer'), to enhance dengue surveillance.			
4 5	586				
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8 9 10		Upwards data transfer (device to surveillance system)			
10 11		A. Test-related data			
12 13		- Date of test (date)			
14		- Geo-location of test (lat, long)			
15 16		- Dengue test result (positive/negative)			
17 18		- Serotype result (DENV1/DENV2/DENV3/DENV4)			
19		B. Identifiers			
20 21		- Name (free text)			
22		- National ID (number)			
23 24		- Home address (free text)			
25 26		- Patient's (or parent/guardian's) telephone number (number)			
27		C. Clinical details			
28 29		- Duration of symptoms in days (number)			
30 31		- Severity of case at time of testing if dengue suspected clinically (non-severe/dengue with			
32		warning signs/severe dengue/patient died)			
33 34		 Alternative clinical diagnos(es), if applicable (free text) 			
35 36		- Additional information for communication to surveillance authority. For example, details			
37		of particularly severe or atypical cases, or those where multiple family members are			
38 39		unwell, which may warrant further investigation (free text)			
40 41		Downwards data transfer (surveillance system to device)			
42 43		- All test-related data (see A, above) from other devices.*			
44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60	588 589 590 591 592	* This information could be output to the clinical user. For example, the number and proportion of recent positive tests in the surrounding area could be displayed, to aid interpretation of the current result. Graphs or maps showing temporal or geographical trends could also be displayed.			

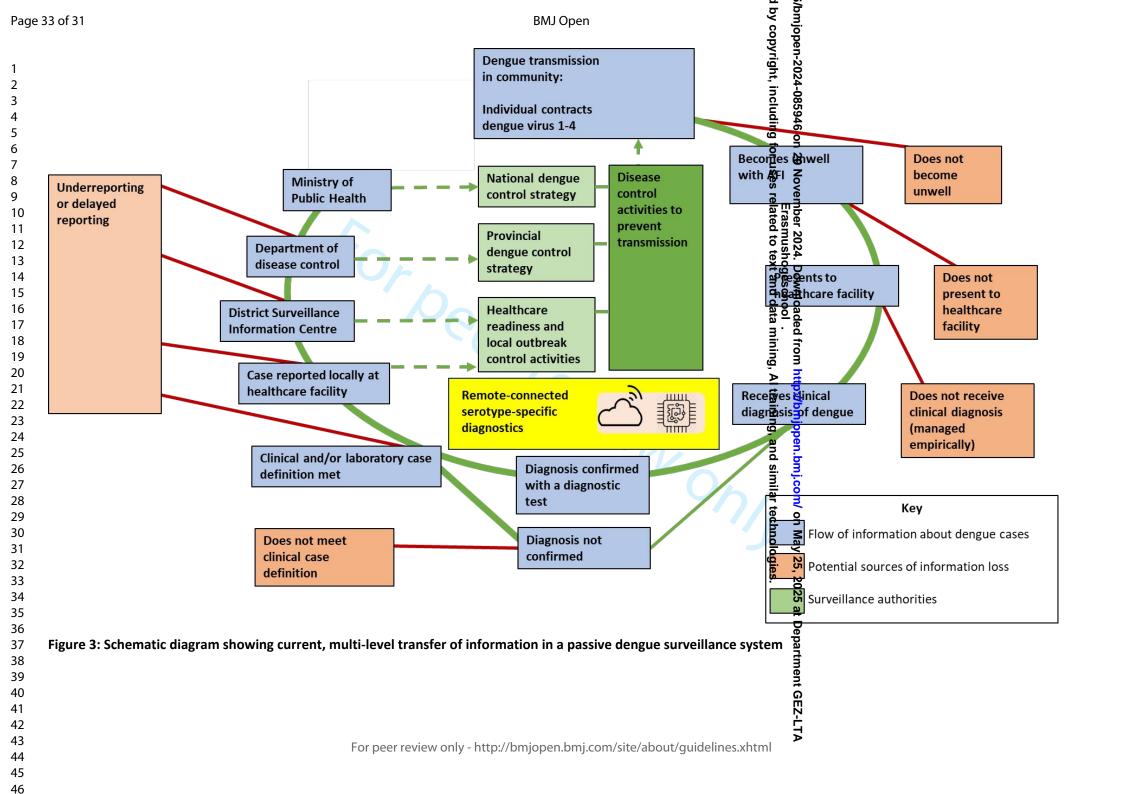
Current practices and challenges



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Diagnostics for optimised dengue surveillance: A qualitative focus group study to investigate user experience and requirements in Thailand

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3	1	Diagnostics for optimised dengue surveillance: A qualitative focus group study to
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6	2	investigate user experience and requirements in Thailand
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24 ABSTRACT

	25	Objectives: Effective, real-time surveillance of dengue may provide early-warning of
0	26	outbreaks and support targeted disease-control intervention but requires widespread
1	27	accurate diagnosis and timely case-reporting. Research directing innovation in diagnostics
2 3 4	28	for dengue surveillance is lacking. This study aimed to describe experience and
5 6 7	29	requirements of relevant prospective users.
8 9 0 1	30	Design: A qualitative, focus group study was conducted.
2 3	31	Participants: Data were collected from 19 users of diagnostic technology who work across
4 5 6	32	the Thai dengue surveillance system.
7 8 9	33	Data collection and analysis: Contextual knowledge, experience and needs were explored in
0 1	34	focus groups. Discussions were translated, transcribed, analysed thematically and mapped
2 3 4	35	to Consolidated Framework for Implementation Research domains.
5 6 7	36	Results: Participants expressed a need for rapid, accurate, serotype-specific tests which can
, 8 9	37	be operated easily by non-expert users without laboratory equipment. They supported
0 1 2	38	integration of diagnostics with surveillance systems and felt this would increase the quantity
2 3 4	39	and speed of case-reporting as well as provide healthcare professionals with up-to-date
5 6	40	information about the number of cases locally, thereby aiding interpretation of test results.
7 8 9	41	Concerns included those relating to data security and the cost of tests.
0 1 2 3	42	Conclusions: Engagement to understand prospective user experience and requirements can
4	43	improve relevance and uptake of new technology, leading to system efficiencies. The
5 6 7 8	44	present study highlights specific needs for accurate, serotype-specific, remote-connected
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3 4	45	diagnostics which are integrated with surveillance systems and support dengue case-
5 6 7	46	reporting at the point-of-care.
8 9	47	KEYWORDS
10 11	48	Dengue [MeSH]
12 13	49	Diagnostic test [MeSH]
14 15	50	Focus group [MeSH]
16 17	51	Infectious disease transmission [MeSH]
18 19	52	Surveillance
20 21	53	User requirements
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Specific investigation into user requirements for diagnostics which support dengue

surveillance.

Included diagnostic technology users in Thailand with a wide range of professional

experience, including those who operate tests and those undertake downstream analysis

and usage of data.

Thematic analysis with mapping to Consolidated Framework for Implementation Research

domains.

Only included participants working within one national surveillance system and excluded

patients and the general public who also play pivotal roles as users.

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67	INTRODUCTION
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Dengue is a mosquito-borne neglected tropical disease which affects 100-400 million individuals annually and is a significant cause of morbidity and mortality among adults and children. It is caused by four dengue virus serotypes (DENV1-4) which co-circulate in many regions.[1] Dengue causes a diverse clinical syndrome ranging from asymptomatic or mild, self-limiting illness to dengue haemorrhagic fever, dengue shock and death.[2], [3] 'Secondary dengue infection', which occurs when an individual is infected for a second (or subsequent) time by a different serotype to their earlier 'primary infection', is most likely to result in severe disease.[4] A diagnosis can be suspected based on clinical features and routinely available laboratory data but should be confirmed using a diagnostic test.[3] Reverse-transcriptase polymerase chain reaction (RT-PCR) assays detect dengue ribonucleic acid. They have high sensitivity and specificity and are considered the modern reference standard.[5] However, RT-PCR requires significant laboratory infrastructure and a skilled workforce, resulting in its limited use in rural and remote locations.[6] Serological techniques (including enzyme-linked immunosorbent assays, ELISAs) can be used to detect host immunoglobulins (IgM and IgG) and virus proteins (non-structural protein 1, NS1). Similar to RT-PCR, laboratory-based serological testing has been challenging to deploy. Therefore, rapid diagnostic tests (RDTs) are more commonly used in rural and remote locations. These are low-cost and simple to use but have varying sensitivity compared to RT-PCR (40% to >90%) and ELISA, which depends on time since onset of symptoms. Additionally, current RDTs cannot determine the infecting serotype.[7]

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	89	Outbreaks of dengue are typically seasonal with the number of cases and proportion
	90	causing severe disease being highly variable between years. Shifts in the predominant
	91	circulating serotype may lead to more severe outbreaks.[8] In 'passive surveillance', cases
)	92	are identified via the routine assessment of unwell patients at healthcare facilities and are
<u>′</u> } }	93	notified to a central surveillance authority. This relies on availability and utilisation of
5	94	accurate diagnostic tests and effective, timely communication of results alongside clinically-
, 3 9	95	derived metadata. Passive surveillance may be augmented at 'sentinel sites', with samples
)	96	undergoing additional serotype-specific testing.[9], [10] Effective implementation of such
<u>)</u> 5	97	systems with real-time data transfer may provide early outbreak warning.[9], [10], [11], [12]
r 5	98	However, common weaknesses include poor access to diagnostic testing and delayed or
7 3	99	incomplete reporting.[9], [13] In Thailand, there is mandatory reporting of clinical or RDT-
)	100	confirmed cases to regional surveillance authorities by healthcare facilities.
<u>2</u> 5 4	101	Several advances in diagnostic technology represent opportunity to enhanced dengue
5	102	surveillance.[14] Novel molecular techniques such as reverse-transcriptase loop-mediated
, 3)	103	isothermal amplification (RT-LAMP) may lead to high-sensitivity portable diagnostic devices
)	104	for detecting and serotyping infections.[15], [16] Mobile phone and global positioning
<u>)</u> } L	105	system (GPS) technologies may be integrated to automate case notification.[12], [17], [18]
	106	In the context of dengue surveillance, 'users' of technology include those involved in the
3	107	operation and interpretation of diagnostic devices, and/or the use of data generated to
)	108	make decisions about management of individual patients and population level surveillance
- } }	109	or disease control.[19] The professional occupation of individuals undertaking these
5	110	activities varies between country and healthcare setting, but may include public health
3	111	practitioners, surveillance officials, doctors, nurses and laboratory scientists. Patients and
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	112	the general public also play pivotal roles as users. Research into user requirements for
	113	diagnostics to enhance dengue surveillance is lacking. Previous studies evaluating the
	114	implementation of existing RDTs for other pathogens have identified some potential
0 1	115	barriers from the perspective of users. These include unreliable supply chains, user training
2 3 4	116	requirements, practical limitations in operating devices, difficulties interpreting and
5 6	117	recording results, distrust of results, and a lack of impact on clinical decision making.[20],
7 8	118	[21], [22], [23], [24] Beyond infectious disease diagnosis and surveillance contexts, there is
9 0 1	119	frequent non-adoption of health technology, including in rural and remote settings.[19],
2 3	120	[25], [26] It is crucial that technology is developed and evaluated in collaboration with
4 5 6	121	intended users. Engagement throughout the design process likely results in optimised
7 8	122	solutions and maximised chances of technology adoption.[27] The Consolidated Framework
9 0 1	123	for Implementation Research (CFIR) provides a set of domains which can be used to
1 2 3	124	systematically assess barriers and facilitators to implementing health intervention. These
4 5	125	include the intervention itself and how it may be adapted, the setting, the processes, and
6 7 8	126	individuals involved. [28]
9 0	107	This study approad users of diagnostic technology working across the Thai dengue
1 2	127	This study engaged users of diagnostic technology working across the Thai dengue
- 3 4	128	surveillance system. It explored their contextual knowledge, experience and needs, with
5 6 7	129	the aim of determining requirements for new devices and their implementation in systems
7 8 9	130	of dengue surveillance.
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4 5	132	METHODS
6 7 8	133	Setting
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3 4	134	This qualitative study was conducted during July 2022 at four institutions in Thailand: The
5 6 7	135	Division of Vector Borne Diseases, Department of Disease Control (CDC) at the Ministry of
8 9	136	Public Health is the national authority responsible for surveillance of dengue and strategies
10 11 12	137	for dengue control. The Hospital for Tropical Diseases (HTD) is a tertiary care hospital
12 13 14	138	specialised in tropical diseases including dengue. Khon Kaen Hospital (KKH) is a public
15 16	139	hospital which provides inpatient and outpatient care for rural patients. The Dengue
17 18 19	140	Haemorrhagic Fever Research Unit at Mahidol University (DHFRU), Bangkok is an academic
20 21	141	centre with a multidisciplinary dengue research portfolio.
22 23 24	142	Participants
24 25		
26 27 28	143	A purposive sample was taken to ensure inclusion of participants with a range of experience
28 29 30	144	across dengue surveillance in Thailand. This included public health practitioners,
31 32	145	surveillance officials, doctors, nurses, laboratory scientists and dengue researchers. One
33 34 35	146	focus group containing at least two of these professional groups was constructed at each of
36 37	147	the above institutions. Participants were identified via their professional relationships with
38 39 40	148	research team members, and were approached during their usual working day.
40 41 42	149	Data collection
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44 45 46	150	Data were collected during four focus group discussions, each including between four and
47 48	151	seven participants. These were facilitated by two researchers and were conducted either in
49 50 51	152	English or Thai language, depending on participant preference. Discussion was facilitated
52 53	153	using a topic guide, developed in advance based on literature review and expert's opinion
54 55 56	154	regarding knowledge and innovations in dengue diagnosis and surveillance (Table 1). This
50 57 58	155	was reviewed and revised iteratively during and between sessions, to ensure that emerging
59 60	156	themes could be identified, explored further and triangulated within and between groups of

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3 4	157	participants. Focus groups were audio-recorded and written notes were taken. Recordings
5 6 7	158	were transcribed and Thai was translated to English language.
8 9 10	159	
11 12 13 14	160	<table 1="" here=""></table>
14 15 16 17	161	
18 19 20	162	Data Analysis
21 22	163	A thematic analysis was undertaken.[29] Transcripts from each focus group were annotated
23 24 25	164	and analysed by two researchers who assigned codes independently and then discussed and
26 27 28	165	aggregated them into themes. A deductive approach was used, with themes mapped to
28 29 30	166	CFIR domains.[28], [30] 'Current practices and challenges' and 'requirements for new
31 32	167	diagnostics in surveillance' were overarching themes agreed <i>a priori</i> , as they were central to
33 34 35	168	the aim of the study.
36 37 38	169	Ethical considerations
39 40 41	170	Potential participants received verbal and written information about the proposed study
42 43	171	purpose and its procedures. All participants provided written informed consent. This study
44 45 46	172	received ethical approval from Mahidol University Faculty of Tropical Medicine Research
47 48 49	173	Ethics Committee (MUTM-2022-031-01)
50 51 52	174	Patient and Public Involvement statement
53 54	175	None.
55 56 57 58 59 60	176	

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3 4 5	177	RESULTS
6 7	178	Nineteen individuals participated, 12 of whom were female. These worked at HTD (6),
8 9 10	179	DHRFU (5), KKH (4) and CDC (4). They included nurses (5), doctors (4), dengue researchers
10 11 12 13	180	(4), laboratory scientists (2), public health practitioners (2) and surveillance officials (2).
14 15	181	Identified themes mapped to the CFIR (Figure 1) demonstrate barriers across all parts of the
16 17 18	182	system including the poor fit between current technologies and adopting context. Features
19 20	183	likely to address these barriers (Figure 2) are also identified, providing viable design and
21 22	184	implementation approaches. These are further described and supported by selected
23 24 25	185	quotations from participants below.
26 27 28 29	186	Current practices and challenges
30 31	187	Diagnosis of dengue: Participants described how individuals with dengue may seek
32 33	188	healthcare at different types of healthcare facility, including primary health centres, district
34 35 36	189	hospitals, regional hospitals, referral hospitals, pharmacies or private clinics, with each type
37 38	190	having different clinical workforce and diagnostic test availability. There is a lack of
39 40 41	191	diagnostic testing in many rural and remote settings.
42 43 44	192	
45 46 47	193	"It depends on the level of [healthcare facility], if located in a very remote area, they cannot
48 49	194	do a blood test."
50 51 52	195	- Participant 6, Laboratory Scientist. Focus group 2.
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"I think the senior doctors like me are very used to following the clinical, but I think the new

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Senior doctors described frequently diagnosing dengue based on clinical features and manysaid they often did not use a diagnostic test.

201 generation of doctors are more likely to use the [RDT]."
202 - Participant 13, Doctor (Paediatrics). Focus group 3.

204 Cited reasons for not testing included a high degree of confidence in clinical diagnoses, 205 potentially inaccurate tests, and resource wasting. Some reported only using tests in 206 atypical cases or outside dengue season.

207 When tests are used, RDTs are operated at laboratories or 'mini laboratories' (non-clinical 4208 areas attached to smaller healthcare facilities), by a laboratory scientist, or sometimes at 53
209 the point-of-care by a nurse. RT-PCR is rarely used because samples (or patients 83
9
210 themselves) must be transported to specialist laboratories and results may be delayed.

Case reporting and information transfer: Participants described a system of passive disease
 surveillance requiring multiple stages of information transfer. Typically, diagnosed cases of
 dengue are communicated to an individual with responsibility for disease reporting at a
 health facility. Information is then transferred sequentially to local, regional and national
 levels of the surveillance system (figure 3).[31] This can written on paper forms which are
 transferred manually between individuals and departments.

2 3	218	<figure 3="" here=""></figure>
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6 7 8	219	
9 10 11	220	This information transfer could be incomplete or delayed, potentially by up to 4 weeks, due
12 13	221	to laborious data input procedures, frequent duplication of tasks and lack of time- and
14 15 16	222	resource- allocation for these activities.
17 18 19	223	
20 21 22	224	"Oh I'm really sad to tell you, not only do we have an underdiagnosis situation, but we
23 24 25	225	have an underreporting situation also."
26 27 28	226	- Participant 17, Senior Surveillance Official. Focus group 4.
29 30 31	227	
32 33 34	228	"One of the reasons they don't report is they have to sit down and key in the result."
35 36 37	229	- Participant 18, Surveillance Official. Focus group 4.
38 39 40	230	
41 42 43	231	Some participants also described a parallel sentinel site surveillance system, with samples
44 45	232	undergoing serotype-specific testing at a central location. However, only low numbers of
46 47 48	233	cases are included, these are not recruited systematically, and batch-testing results in
49 50 51	234	availability of serotype data being delayed.
52 53 54	235	Use of surveillance data: When participants were asked about the benefits of case-
55 56	236	reporting, responses varied according to professional occupation. Doctors, nurses and
57 58 59 60	237	laboratory scientists did not identify benefits from this activity and were unaware of

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4	238	downstream processes . They rarely received epidemiological information or warning about
5 6	239	outbreaks as a result participation in surveillance.
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8 9	240	
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12 13	241	"No one tells us, we just know when a large number of patients is coming!"
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15 16	242	- Participant 13, Doctor (Paediatrics). Focus group 3.
17 18	243	
19 20	245	
21	244	Public health practitioners and surveillance officials explained how national and regional
22	277	
23 24	245	data is collated into reports but agreed that information could be disseminated more rapidly
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26	246	and used more efficiently locally.
27 28		
20 29	247	
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33	248	Requirements for new diagnostics in surveillance
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35 36	249	Use setting and operator skillset: Participants stated that new devices for the diagnosis of
30 37		
38 39	250	dengue should be usable in a wide range of settings, including at the point-of-care (inpatient
40	251	and outpatient) and in laboratories and 'mini laboratories'. There was a preference for
41	201	
42 43	252	analysing a small volume (up to 4 drops, ~140uL) of capillary blood, obtainable by finger-
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45	253	prick and transferred directly into the device.
46 47		
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49	254	
49 50	254	
49 50 51	254 255	<i>"If we use it in outpatients where there are many patients, obtaining blood from the</i>
49 50 51 52 53	255	
49 50 51 52 53 54		<i>"If we use it in outpatients where there are many patients, obtaining blood from the fingertip would be suitable"</i>
49 50 51 52 53 54 55	255	
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49 50 51 52 53 54 55 56 57 58	255 256	fingertip would be suitable"
49 50 51 52 53 54 55 56 57	255 256	fingertip would be suitable"

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3 4	259	There was a strong desire for minimal sample processing prior to analysis (i.e.
5 6 7	260	centrifugation, pipetting, mixing or addition of reagents). This was frequently explained by
7 8 9	261	reference to currently available RDTs, which are simple to use.
10 11 12 13	262	
14 15 16	263	"Nurses are not using pipette. If that's needed, it needs to be in the lab."
17 18 19	264	- Participant 7, Nurse Assistant (Outpatients). Focus group 2.
20 21 22	265	
23 24 25	266	"We have to try to mimic the [RDTs]"
26 27 28	267	- Participant 3, Dengue Researcher. Focus group 1.
29 30 31 32	268	
33 34	269	Diagnostic targets: Many participants stated that new diagnostic devices should have the
35 36 27	270	ability to serotype infections. Public health practitioners, surveillance officials and several
37 38 39	271	dengue researchers had particularly strong desires for this, noting that it has not been
40 41 42	272	achieved by currently available RDTs.
43 44 45	273	
46 47 48	274	"If we can get the serotype in real-time of course it will make our control measures more
49 50 51	275	effective."
52 53 54	276	- Participant 19, Surveillance Official. Focus group 4.
55 56 57	277	
57 58 59	278	Doctors and nurses could also understand this potential surveillance benefit but stated that
60	279	serotypes are of little consequence for individual patient management.

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6 7	281	Assay performance characteristics and implications for clinical and public health
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9	282	management of dengue: Most participants cited 'accuracy' as an important characteristic.
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11 12	283	They recognised that existing dengue tests sometimes had low sensitivity, which could
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14	284	affect patient management as well as surveillance. Low sensitivity tests which give falsely
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16	285	negative results may lead missed diagnoses of dengue, with further testing and treatments
17 18		
19	286	for other causes (for example bacterial infections) being initiated or continued
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21	287	unnecessarily.
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27	289	"If the doctors see that the test is negative, [they] might diagnose something else and treat
28 29		
30	290	something else, like bacterial infection [this] might harm the patient."
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32	201	Dertisinent 10. Dester (Internel Medicine) Feeus group (
33 34	291	 Participant 10, Doctor (Internal Medicine). Focus group 4.
35		
36	292	
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38 39	293	They suggested that new devices should have at least the same sensitivity as currently
40	293	They suggested that new devices should have at least the same sensitivity as currently
41	294	available RDTs.
42	294	available RDTS.
43 44		
44 45	295	Participants also recognised that non-specific tests could lead to alternative diagnoses being
46		
47	296	missed and discontinuation of important treatments (for example antibiotics).
48		
49 50	207	
51	297	
52		
53	298	<i>"If it has false positive it may lead to mistreatment of other diseases"</i>
54 55		
56	200	Darticipant 16 Dector (Internal Madicina) Facus group 2
57	299	- Participant 16, Doctor (Internal Medicine). Focus group 3.
58		
59 60	300	
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2		
3 4	301	"This means it's not dengue but something else. Yes definitely, this delays the treatment.
5 6 7	302	Yes it's going to be a problem."
8 9 10	303	- Participant 10, Doctor (Internal Medicine). Focus group 4.
11 12 13 14	304	
15 16	305	They caveated this by suggesting that users would become familiar with the performance of
17 18	306	any new test, and would interpret results accordingly. They also described how clinical and
19 20 21	307	epidemiological context are considered, when interpreting dengue test results.
22 23 24 25	308	
26 27	309	"We use it along with [routine laboratory data]. If [the test] is negative, but the case is likely
28 29 30	310	to be dengue, we still have [routine laboratory data] to follow-up the patient"
31 32 33	311	- Participant 16, Doctor (Internal Medicine). Focus group 3.
34 35 36 37	312	
37 38 39	313	<i>"If the local prevalence of the infection is high, then the test-negative will not ensure that the</i>
40 41	314	patient has no dengue infection. But if the patient is in a without dengue area, we will have
42 43 44	315	high confidence that this patient does not have dengue infection. It will depend on the
45 46 47	316	prevalence at the time and in the local area."
48 49 50	317	- Participant 16, Doctor (Internal Medicine). Focus group 3.
51 52 53	318	
54 55	319	Many participants also cited 'fast result' as an important characteristic. This was particularly
56 57 58 59 60	320	important for nurses and laboratory scientists who are frequent operators of RDTs. They

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suggested target sample-to-result time should be below one hour (and ideally below 15-20 minutes).

The 'ability to quantify virus' was not considered an important characteristic, either for clinical or surveillance purposes. However, some participants acknowledged potential utility in clinical research, for example in trials of antiviral mediations.

Connectivity and metadata: Participants recommended that diagnostic devices should have a simple way of displaying results to users with low chance of misinterpretation. They also stated that results should be recorded permanently on a patient's record. This could be achieved by integrating devices with electronic patient records and/or laboratory information systems, or by allowing results to be printed. There was agreement among all participants that integrating diagnostic devices with surveillance systems could be helpful, and that receiving serotype data would support surveillance efforts. Many suggested that it would reduce requirements for informal communication, paper records, data input and duplication of work at several levels of the surveillance system, hence improving case reporting. Public health practitioners and surveillance officials detailed which metadata should be reported routinely alongside the test results (Table 2). They also felt that optional reporting of pertinent clinical details could be useful (for example details of particularly severe or atypical cases which may warrant

<Table 2 here>

further investigation).

1 ว		
2 3	343	
4 5	545	
6 7	344	As well as performing automated case notification ('upwards data transfer'), participants
8 9 10	345	suggested that a new diagnostic device could also receive and display epidemiological data
11 12	346	to the user ('downwards data transfer'). They expressed their desires for up-to-date
13 14 15	347	information about the numbers and severity of dengue cases in their area and agreed that
16 17	348	devices which provide early warning of dengue outbreaks would be useful.
18 19 20 21	349	
22 23 24	350	<i>"If we know the information about the outbreak of dengue cases in the surrounding area, we</i>
25 26	351	will be more aware of the possibility of more severe cases coming to the hospital"
27 28 29	352	- Participant 13, Doctor (Paediatrics). Focus group 3.
30 31 32 33	353	
34 35	354	Some explained how this knowledge could be used to assist in the interpretation of the
36 37 38	355	dengue test itself.
39 40 41	356	
42 43 44	357	"When patients present with fever during the outbreak season the clinician usually ask
45 46	358	where they come from. If we know that they come from an outbreak area, it increases the
47 48 49	359	possibility that the case may be dengue"
50 51 52	360	- Participant 13, Doctor (Paediatrics). Focus group 3.
53 54 55 56 57 58 59	361	
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2		
3 4	362	However, some participants had concerns relating to data security, particularly if devices
5 6 7	363	could receive, store or display potentially sensitive information about other cases in the
, 8 9	364	region (for example their location).
10 11 12 13	365	
14 15	366	"Someone can think about stigmatisation. OK so this family has dengue and someone can
16 17 18	367	think that they are spreading dengue to the village, or something like that."
19 20 21	368	- Participant 10, Doctor (Internal Medicine). Focus group 2.
22 23 24	369	
25 26 27	370	Cost: Participants emphasised the importance of cost when considering the potential
28 29	371	introduction of new diagnostic devices in Thailand. Usually, diagnostic testing is paid for by
30 31 32	372	government insurance coverage, private insurance, or personal funds. Many participants
33 34	373	considered a conceptual difference between testing which is undertaken for individual
35 36 37	374	patient benefit (i.e. for diagnostic purposes) and that which is undertaken for potential
38 39	375	collective population benefit (i.e. for surveillance), and felt that using personal funds to pay
40 41 42	376	for the latter would be unfair.
43 44 45	377	for the latter would be unfair.
46 47 48	378	DISCUSSION
49 50 51	379	Participants in this study identified the need and potential value of new tests for dengue
52 53	380	which are accurate, rapid, low cost and can be operated easily by non-expert users outside
54 55 56	381	laboratory settings, including in remote and rural areas. They supported integration of
57 58	382	diagnostic devices with surveillance systems to increase quantity and speed of case-
59 60	383	notification. These requirements align with The World Health Organization (WHO) Special
		20

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1 2

2 3 4	384	Program for Research and Training in Tropical Diseases 'ASSURED' criteria for diagnostics,
5 6 7	385	and subsequent publications supporting real-time connectivity ('REASSURED'
7 8 9	386	characteristics). [32], [33], [34] Tests which can serotype may be important for surveillance
10 11	387	but are less likely to benefit individual patients. As well as 'upwards data transfer' (such
12 13 14	388	that cases are notified by devices to the surveillance authority), it was felt that 'downwards
15 16	389	data transfer' (from the surveillance system to each diagnostic device) would also be useful.
17 18 19	390	This could provide healthcare professionals with up-to-date information about local dengue
20 21	391	cases, assisting them in the interpretation of individual test results and potentially warning
22 23 24	392	them of outbreaks. Cautions relating to this overall approach included data security and the
24 25 26	393	potential cost when compared to currently available diagnostic tests.
27 28 29	394	Previous studies have explored healthcare workers' and community members' perceptions
30 31	395	of new diagnostic devices for tropical infections, particularly those intended to be used at
32 33 34	396	the point-of-care. Diggle et al investigated malaria RDTs in Northern Kenya and found
35 36	397	significant knowledge gaps, misconceptions and evidence of low uptake. Reasons included
37 38	398	perceptions that testing was unnecessary, distrust of results, fear that devices might also
39 40 41	399	test for other, potentially stigmatised conditions, and cost. However, RDTs were noted for
42 43	400	their ease of use and portability.[21] Rasti et al investigated Southwestern Ugandan
44 45 46	401	healthcare workers who described point-of-care tests improving diagnosis and clinical
47 48	402	decision making in under-resourced areas. However, they also reported experiencing
49 50 51	403	inaccurate results and a need to interpret and corroborate results with other clinical
52 53	404	information.[23] Boadu et al identified influencers of malaria RDT implementation among
54 55 56	405	primary healthcare providers in central Ghana. These included healthcare delivery
57 58	406	constraints, provider perceptions and social dynamics of care delivery.[20] A scoping review
59 60	407	of the use of mobile phones in the prevention and control of arboviral infections identified

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2 3 4	408	six studies where mobile phone technology formed part of a diagnostic workflow, and 25
5 6 7	409	studies where mobile telephones were used in various surveillance activities.[35] Cited
7 8 9	410	benefits were a 'reduction in error of transcribed data', 'rapid data transfer', and 'good
10 11 12	411	completeness in terms of more dengue case reporting', which are highly relatable to the
13 14	412	present study's findings.[35] Another recent article has reviewed various digital health
15 16 17	413	interventions which have been used in dengue surveillance.[36]
18 19	414	This study is the first to specifically investigate user requirements for diagnostic devices that
20 21 22	415	would optimise dengue surveillance. It collected data from a wide range of diagnostic
23 24 25	416	technology users, including those who make decisions to test, those with hands-on
25 26 27	417	experience of operating tests, and those who are involved in downstream analysis and
28 29 30	418	usage of data. Broad inclusion appears to have been important because user requirements
30 31 32	419	sometimes varied between occupational groups. Innovation in technology should account
33 34 35	420	for this and may need to balance priorities of different users.
36 37	421	Limitations of this study include its restriction to 19 participants in one country, which could
38 39 40	422	mean that findings are geographically specific and are not fully representative nor
41 42	423	transferrable to other settings. However, many of the practices and challenges described
43 44 45	424	appear similar to those experienced in other Southeast Asian nations[9] and more
46 47	425	widely.[13] Additionally, it did not include patients or members of the general public, who
48 49 50	426	are important users of diagnostic technology. In Thailand, there has been rapid increase in
51 52	427	the use of mobile phone technology, including for storage and sharing of personal health
62		
53 54 55	428	records.[37], [38] Results from the present study highlight further need to engage this
54 55 56 57	428 429	records.[37], [38] Results from the present study highlight further need to engage this group, particularly around the importance of data security. Furthermore, this study
54 55 56		

1 2

> ther settings. However, many of the practices and challenges described those experienced in other Southeast Asian nations[9] and more onally, it did not include patients or members of the general public, who rs of diagnostic technology. In Thailand, there has been rapid increase in phone technology, including for storage and sharing of personal health Results from the present study highlight further need to engage this y around the importance of data security. Furthermore, this study ue, but there is likely to be significant overlap in the experiences and 22

3 4	431	requirements of individuals who undertake surveillance of other arboviruses and other
5 6 7	432	infectious disease more generally. Surveillance requirements for devices which may
8 9	433	simultaneously detect multiple relevant pathogens should also be investigated, as
10 11 12	434	diagnostic technology advances.
13 14 15	435	Dengue is a major public health concern across tropical regions. Accurate, serotype-specific,
16 17 18	436	remote-connected diagnostic devices which can be used in a diverse range of settings would
19 20	437	enhance surveillance and could support real-time outbreak risk-assessment and warning.
21 22 23	438	These should be developed in collaboration with a range of prospective technology users.
23 24 25 26	439	
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33 34 35	442	their time and shared their experiences.
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49 50 51	448	(RED) program, Faculty of Medicine Siriraj Hospital, Mahidol University.
52 53 54	449	
55 56 57	450	COMPETING INTERESTS
58 59 60	451	All authors declare that there are no competing interests.

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3 4 5	452	
6 7 8	453	AUTHOR CONTRIBUTIONS
9 10	454	PArkell, SK, AS, DM, RA and SL designed the study. PArkell, SK and SL collected data. PArkell
11 12 13	455	and SK analysed data and drafted the manuscript. JR, PG, PM, PAvirutnan and AH were
14 15 16	456	awarded funding to collaborate and undertake a programme of dengue diagnostics
17 18	457	development which includes this qualitative work. All authors critically appraised the
19 20 21	458	manuscript and agreed to its submission for publication. PA is responsible for the overall
22 22 23	459	content. PA is the corresponding author and attests that all listed authors meet authorship
24 25 26	460	criteria and that no others meeting the criteria have been omitted. PA is the guarantor.
27 28 29	461	
30 31 32	462	DATA AVAILABILITY
33 34	463	Data are available upon reasonable request to PA, subject to an appropriate data sharing
35 36 37	464	agreement being implemented.
38 39 40 41	465	
42 43 44	466	FIGURE CAPTIONS
45 46 47	467	Figure 1
48 49	468	Identified themes within 'current practices and challenges relating to dengue diagnosis and
50 51 52	469	surveillance' mapped to the Consolidated Framework for Implementation Research (CFIR)
53 54	470	domains. Inner figure reproduced with permission from the original open access
55 56 57	471	publication, available at: https://cfirguide.org/cfirdiagram/.
58 59 60	472	Figure 2

2		
3	473	Identified themes within 'requirements for new diagnostics' mapped to the Consolidated
4		
5 6	474	Framework for Implementation Research (CFIR) domains. Inner figure reproduced with
7		
8	475	permission from the original open access publication, available at:
9		
10 11	476	https://cfirguide.org/cfirdiagram/.
12		
13		
14	477	Figure 3
15 16		
17	478	Schematic diagram showing current, multi-level transfer of information in a passive dengue
18		
19	479	surveillance system. Information is predominantly transferred 'upwards', with limited
20	-	
21 22	480	'downwards data transfer' to communities and users.
23		
24		
25	481	
26 27		
28	482	ETHICS APPROVAL
29	-	
30		
31 32	483	Potential participants received verbal and written information about the proposed study
33		
34	484	purpose and its procedures. All participants provided written informed consent. This study
35		
36 37	485	received ethical approval from Mahidol University Faculty of Tropical Medicine Research
38		
39	486	Ethics Committee (MUTM-2022-031-01)
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43	624		<i>Science and Engineering</i> , WCSE, 2019. doi: 10.18178/wcse.2019.06.009.
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Α.	Contextual understanding and needs assessment.
-	How is dengue surveillance done, at your workplace (and more broadly)?
-	Where do patients present to with symptoms of dengue and how do they get diagno
-	If tests are not always done, why do you think this is?
-	Where / how should cases of dengue get reported, to surveillance?
-	If positive results are not always reported, why do you think this is?
-	How are surveillance data used?
В.	Requirements for new diagnostic devices: The assay.
-	Where does diagnostic testing usually occur, and what laboratory equipment is avail there (if any)?
-	Who typically operates diagnostic devices, and what sample preparation / analysis sl do they have (if any)?
-	What do you think would be the preferred sample type and sample volume, that wo into any new diagnostic device?
-	What do you think would be the preferred (and maximum) time from sample to resu (i.e. test duration), of any new diagnostic device?
-	What do you think the preferred (and minimum) sensitivity and specificity, of any ne diagnostic device?
-	Is knowing the dengue serotype important?
-	Is knowing the quantity of dengue (level of 'viraemia') in a patient's sample importar
C.	Requirements for new diagnostic devices: Remote connectivity and reporting.
-	How are results from diagnostic tests generally reported, and where are they stored
-	If a new diagnostic device could be remote-connected, where should results be repo to?
-	Which information about cases would be most useful to report alongside test results enhance dengue surveillance?
-	Would it be useful if a new diagnostic device could receive and display real-time information about local dengue incidence to the user (as well as transmitting data for case-reporting)?

Page 32 of 33

630	Table 2: Metadata which could be reported automatically from diagnostic devices to the			
631	surveillance authority ('upwards data transfer') and from surveillance to the diagnostic device			
632	('downwards data transfer'), to enhance dengue surveillance.			
	Upwards data transfer (device to surveillance system)			
	A. Test-related data			
	- Date of test (date)			
	- Geo-location of test (lat, long)			
	- Dengue test result (positive/negative)			
	- Serotype result (DENV1/DENV2/DENV3/DENV4)			
	B. Identifiers			
	- Name (free text)			
	- National ID (number)			
	- Home address (free text)			
	- Patient's (or parent/guardian's) telephone number (number)			
	C. Clinical details			
	- Duration of symptoms in days (number)			
	- Severity of case at time of testing if dengue suspected clinically (non-severe/dengue wit			
	warning signs/severe dengue/patient died)			
	- Alternative clinical diagnos(es), if applicable (free text)			
	- Additional information for communication to surveillance authority. For example, detai			
	of particularly severe or atypical cases, or those where multiple family members are			
	unwell, which may warrant further investigation (free text)			
	Downwards data transfer (surveillance system to device)			
	- All test-related data (see A. above) from other devices.*			
634	 All test-related data (see A, above) from other devices.* * This information could be output to the clinical user. For example, the number and propor of recent positive tests in the surrounding area could be displayed, to aid interpretation of the current result. Graphs or maps showing temporal or geographical trends could also be displayed 			

Pag<mark>e 33 of 33</mark>

Current practices and challen

Diagnosis of dengue

Diagnosis of dengue

nurses conduct testing

report cases and analyse data

processes and don't use data

Use of surveillance data

remote settings

facility

facility

2025

at Department GEZ-

Health seeking at different types of healthcare

Testing infrastructure not available in rural and

Available clinical workforce depends on health

Doctors request test, laboratory personnel or

Surveillance officials collate and analyse data

Doctors, nurses and lab scientists unaware of

Multiple individuals at various administrative levels

Case reporting and information transfer

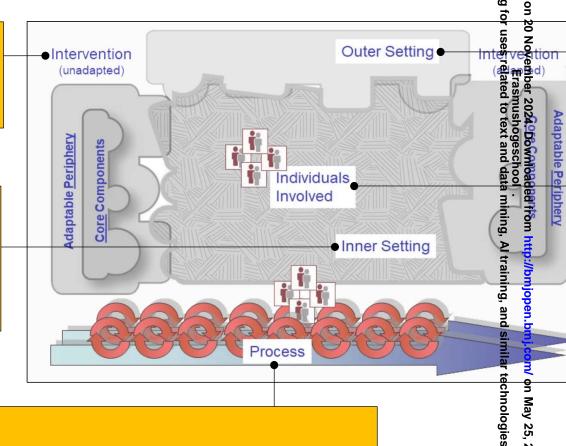
(Laboratory and/or transport infrastructure)



Diagnosis of dengue Use of RDTs (less accurate, do not serotype) RT-PCR assays for serotyping at sentinel sites only

Diagnosis of dengue

Clinicians often diagnose
 dengue clinically
 (Do not use tests because they
 may not be useful and are
 considered wasteful, unless
 atypical/outside season)



Diagnosis of dengue

Batch testing causes delays

Case reporting and info transfer

Passive surveillance requires multiple stages of information transfer Additional parallel sentinel site surveillance for serotyping, but lack of systematic sampling

Laborious data input procedures and duplication of tasks

Lack of resource allocation for surveillance tasks

Use of surveillance data

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Lack of timely dissemination of case data locally

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Requirements for new diagnostics in street ance

4Cost relate Outer Setting ⁵Acceptable cost within Intervention Intervention (unadapted) Thai healthcare system (adapted) ⁸Consideration of who 9should pay for tests when Downloaded from http://bmjopen.bm)geschool. Core Components laptab ¹Ørimary purpose is daptable Periphery Components ¹disease surveillance e Individuals Periphery mining, 13 14 Involved 15 Core Al training Bequired use setting Inner Setting 1and operator skillset 1Devices should be usable and simila ²fh laboratories, mini- $\frac{2l}{2}$ aboratories and ideally at ²the point-of-care 24 čhn 25 26 olog <u>a</u> 27 N ²Connectivity and metadata 2025 ²⁹ 38 imple result output format required 3\$hould go to patient, clinical records and surveillance system 32 Jpwards data transfer': Results to surveillance system (alongside clinical metadata and pertinent details from ³elinical team) 34 Downwards data transfer': Information on number and severity of cases occurring locally (for outbreak 35 jpreparedness and assistance interpreting test results) 3 Concerns about data security 38 39

41

Required use setting and operator skillset

Small volume (140uL) of whole capillary blood Minimal sample processing (similar to currently available RDTs)

Required diagnostic targets

Differentiation of dengue virus serotypes important for surveillance and research (but not for clinical case management)

Required performance characteristics and implications for clinical and public health management of dengue

High accuracy at all disease stages (at least comparable to currently available RDTs)

Sensitive such that cases are not missed

Specific so other diagnoses are not overlooked and

undertreated

Fast time-to-result (less than 1 hour)

Ouantification of virus may be important in research

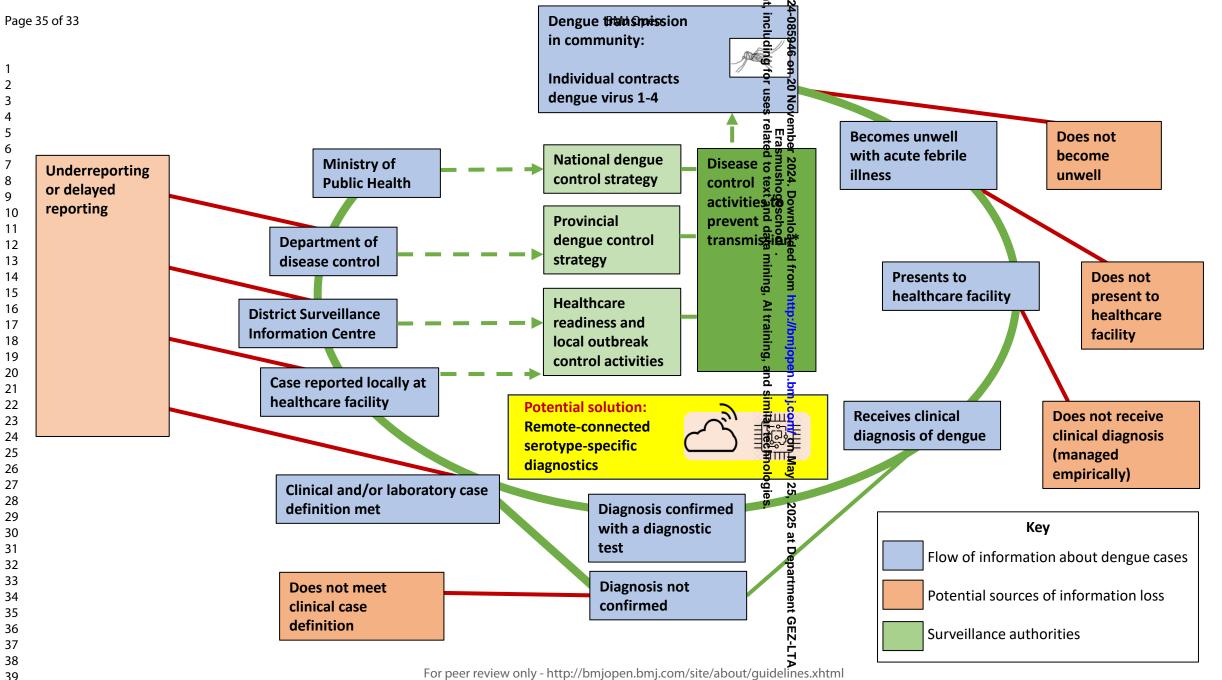
Required performance characteristics and implications for clinical and public health management of dengue

Users become familiar with performance of tests and interpret results accordingly (alongside other data, and according to seasonality of dengue transmission)

Connectivity and metadata

Acceptability of data sharing to patients and their families, potential for stigma

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* Current disease control activities comprise environmental management and insecticide use. Future activities may also include deployment of vaccines and Wolbachia-infected mosquitos.

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Diagnostics for optimised dengue surveillance: A qualitative focus group study to investigate user experience and requirements in Thailand

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3	1	Diagnostics for optimised dengue surveillance: A qualitative focus group study to
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6	2	investigate user experience and requirements in Thailand
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24 ABSTRACT

1 2

	25	Objectives: Effective, real-time surveillance of dengue may provide early-warning of
0	26	outbreaks and support targeted disease-control intervention but requires widespread
1	27	accurate diagnosis and timely case-reporting. Research directing innovation in diagnostics
2 3 4	28	for dengue surveillance is lacking. This study aimed to describe experience and
5 6 7	29	requirements of relevant prospective users.
8 9 0 1	30	Design: A qualitative, focus group study was conducted.
2 3	31	Participants: Data were collected from 19 users of diagnostic technology who work across
4 5 6	32	the Thai dengue surveillance system.
7 8 9	33	Data collection and analysis: Contextual knowledge, experience and needs were explored in
0 1	34	focus groups. Discussions were translated, transcribed, analysed thematically and mapped
2 3 4	35	to Consolidated Framework for Implementation Research domains.
5 6 7	36	Results: Participants expressed a need for rapid, accurate, serotype-specific tests which can
, 8 9	37	be operated easily by non-expert users without laboratory equipment. They supported
0 1 2	38	integration of diagnostics with surveillance systems and felt this would increase the quantity
2 3 4	39	and speed of case-reporting as well as provide healthcare professionals with up-to-date
5 6	40	information about the number of cases locally, thereby aiding interpretation of test results.
7 8 9 0	41	Concerns included those relating to data security and the cost of tests.
0 1 2	42	Conclusions: Engagement to understand prospective user experience and requirements can
3 4	43	improve relevance and uptake of new technology, leading to system efficiencies. The
5 6 7 8 9	44	present study highlights specific needs for accurate, serotype-specific, remote-connected

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2 3	45	diagnostics which are integrated with surveillance systems and support dengue case-
4 5	46	reporting at the point-of-care.
6 7	40	
8 9	47	KEYWORDS
10 11	48	Dengue [MeSH]
12 13	49	Diagnostic test [MeSH]
14 15	50	Focus group [MeSH]
16 17	51	Infectious disease transmission [MeSH]
18 19	52	Surveillance
20 21	53	User requirements
22 23	54	
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STRENGTHS AND LIMITATIONS OF THIS STUDY

- Specific investigation into user requirements for diagnostics which support dengue • surveillance.
- Included technology users in Thailand with wide ranging professional experience • including operation of tests and downstream analysis/usage of data.
- • Thematic analysis with mapping to Consolidated Framework for Implementation Research domains.
- Only included participants working within one national surveillance system and
 - genera excluded patients and the general public who also play pivotal roles as users.

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66 I	NTRODUCTION
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Dengue is a mosquito-borne neglected tropical disease which affects 100-400 million individuals annually and is a significant cause of morbidity and mortality among adults and children. It is caused by four dengue virus serotypes (DENV1-4) which co-circulate in many regions.[1] Dengue causes a diverse clinical syndrome ranging from asymptomatic or mild, self-limiting illness to dengue haemorrhagic fever, dengue shock and death.[2], [3] 'Secondary dengue infection', which occurs when an individual is infected for a second (or subsequent) time by a different serotype to their earlier 'primary infection', is most likely to result in severe disease.[4] A diagnosis can be suspected based on clinical features and routinely available laboratory data but should be confirmed using a diagnostic test.[3] Reverse-transcriptase polymerase chain reaction (RT-PCR) assays detect dengue ribonucleic acid. They have high sensitivity and specificity, are considered the modern reference standard diagnostic test, and may be used to serotype infections.[5] However, RT-PCR requires significant laboratory infrastructure and a skilled workforce, resulting in its limited use in rural and remote locations.[6] Serological techniques (including enzyme-linked immunosorbent assays, ELISAs) can be used to detect host immunoglobulins (IgM and IgG) and virus proteins (non-structural protein 1, NS1). Similar to RT-PCR, laboratory-based serological testing has been challenging to deploy. Therefore, rapid diagnostic tests (RDTs), which also detect IgM, IgG and/or NS1, are more commonly used in rural and remote locations. These are low-cost and simple to use but have varying sensitivity compared to RT-PCR (40% to >90%) and ELISA, which depends on time since onset of symptoms. Current RDTs cannot determine the infecting serotype.[7]

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	89	Outbreaks of dengue are typically seasonal with the number of cases and proportion
	90	causing severe disease being highly variable between years. Shifts in the predominant
	91	circulating serotype may lead to more severe outbreaks.[8] In 'passive surveillance', cases
	92	are identified via the routine assessment of unwell patients at healthcare facilities and are
: ; ;	93	notified to a central surveillance authority. This relies on availability and utilisation of
	94	accurate diagnostic tests and effective, timely communication of results alongside clinically-
, ,	95	derived metadata. Passive surveillance may be augmented at 'sentinel sites', with samples
)	96	undergoing additional serotype-specific testing.[9], [10] Effective implementation of such
<u>-</u> 	97	systems with real-time data transfer may provide early outbreak warning.[9], [10], [11], [12]
	98	However, common weaknesses include poor access to diagnostic testing and delayed or
}	99	incomplete reporting.[9], [13] In Thailand, there is mandatory reporting of clinical or RDT-
,) 1	.00	confirmed cases to regional surveillance authorities by healthcare facilities.
1	.01	Several advances in diagnostic technology represent opportunity to enhanced dengue
, 1	.02	surveillance.[14] Novel molecular techniques such as reverse-transcriptase loop-mediated
, 1	.03	isothermal amplification (RT-LAMP) may lead to high-sensitivity portable diagnostic devices
) 1	.04	for detecting and serotyping infections.[15], [16] Mobile phone and global positioning
1	.05	system (GPS) technologies may be integrated to automate case notification.[12], [17], [18]
1	.06	In the context of dengue surveillance, 'users' of technology include those involved in the
, 1	.07	operation and interpretation of diagnostic devices, and/or the use of data generated to
) 1	.08	make decisions about management of individual patients and population level surveillance
1	.09	or disease control.[19] The professional occupation of individuals undertaking these
; ; 1	.10	activities varies between country and healthcare setting, but may include public health
1	.11	practitioners, surveillance officials, doctors, nurses and laboratory scientists. Patients and
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	112	the general public also play pivotal roles as users. Research into user requirements for
	113	diagnostics to enhance dengue surveillance is lacking. Previous studies evaluating the
	114	implementation of existing RDTs for other pathogens have identified some potential
0 1	115	barriers from the perspective of users. These include unreliable supply chains, user training
2 3 4	116	requirements, practical limitations in operating devices, difficulties interpreting and
5 6	117	recording results, distrust of results, and a lack of impact on clinical decision making.[20],
7 8	118	[21], [22], [23], [24] Beyond infectious disease diagnosis and surveillance contexts, there is
9 0 1	119	frequent non-adoption of health technology, including in rural and remote settings.[19],
2 3	120	[25], [26] It is crucial that technology is developed and evaluated in collaboration with
4 5 6	121	intended users. Engagement throughout the design process likely results in optimised
7 8	122	solutions and maximised chances of technology adoption.[27] The Consolidated Framework
9 0 1	123	for Implementation Research (CFIR) provides a set of domains which can be used to
2 3	124	systematically assess barriers and facilitators to implementing health intervention. These
4 5	125	include the intervention itself and how it may be adapted, the setting, the processes, and
6 7 8	126	individuals involved. [28]
9 0	127	This study engaged users of diagnostic technology working across the Thai dengue
1 2	127	This study engaged users of diagnostic technology working across the that deligue
3 4	128	surveillance system. It explored their contextual knowledge, experience and needs, with
5 6 7	129	the aim of determining requirements for new devices and their implementation in systems
/ 8 9	130	of dengue surveillance.
0 1	131	
2 3		
4 5	132	METHODS
6 7 8	133	Setting
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1 2		
3 4	134	This qualitative study was conducted during July 2022 at four institutions in Thailand: The
5 6 7	135	Division of Vector Borne Diseases, Department of Disease Control (CDC) at the Ministry of
8 9	136	Public Health is the national authority responsible for surveillance of dengue and strategies
10 11 12	137	for dengue control. The Hospital for Tropical Diseases (HTD) is a tertiary care hospital
12 13 14	138	specialised in tropical diseases including dengue. Khon Kaen Hospital (KKH) is a public
15 16	139	hospital which provides inpatient and outpatient care for rural patients. The Dengue
17 18 19	140	Haemorrhagic Fever Research Unit at Mahidol University (DHFRU), Bangkok is an academic
20 21	141	centre with a multidisciplinary dengue research portfolio.
22 23 24	142	Participants
24 25		
26 27	143	A purposive sample was taken to ensure inclusion of participants with a range of experience
28 29 30	144	across dengue surveillance in Thailand. This included public health practitioners,
31 32	145	surveillance officials, doctors, nurses, laboratory scientists and dengue researchers. One
33 34 35	146	focus group containing at least two of these professional groups was constructed at each of
36 37	147	the above institutions. Participants were identified via their professional relationships with
38 39 40	148	research team members, and were approached during their usual working day.
40 41		
42 43	149	Data collection
44 45 46	150	Data were collected during four focus group discussions, each including between four and
47 48	151	seven participants. These were facilitated by two researchers and were conducted either in
49 50 51	152	English or Thai language, depending on participant preference. Discussion was facilitated
52 53	153	using a topic guide, developed in advance based on literature review and expert's opinion
54 55 56	154	regarding knowledge and innovations in dengue diagnosis and surveillance (Table 1). This
56 57 58	155	was reviewed and revised iteratively during and between sessions, to ensure that emerging
59 60	156	themes could be identified, explored further and triangulated within and between groups of

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3 4	157	participants. Focus groups were audio-recorded and written notes were taken. Recordings
5 6 7	158	were transcribed and Thai was translated to English language.
8 9 10	159	
11 12 13	160	<table 1="" here=""></table>
14 15 16	161	
17 18 19	162	Data Analysis
20 21 22	163	A thematic analysis was undertaken.[29] Transcripts from each focus group were annotated
23 24 25	164	and analysed by two researchers who assigned codes independently and then discussed and
23 26 27	165	aggregated them into themes. A deductive approach was used, with themes mapped to
28 29	166	CFIR domains.[28], [30] 'Current practices and challenges' and 'requirements for new
30 31 32	167	diagnostics in surveillance' were overarching themes agreed a priori, as they were central to
33 34	168	the aim of the study.
35 36 37 38	169	Ethical considerations
39 40 41	170	Potential participants received verbal and written information about the proposed study
42 43	171	purpose and its procedures. All participants provided written informed consent. This study
44 45	172	received ethical approval from Mahidol University Faculty of Tropical Medicine Research
46 47 48	173	Ethics Committee (MUTM-2022-031-01)
49 50 51	174	Patient and Public Involvement statement
52 53 54	175	This current phase of research and development did not include patients or public
55 56 57 58 59 60	176	representatives.

2		
3 4 5	177	RESULTS
6 7	178	Nineteen individuals participated, 12 of whom were female. These worked at HTD (6),
8 9 10	179	DHRFU (5), KKH (4) and CDC (4). They included nurses (5), doctors (4), dengue researchers
11 12 13	180	(4), laboratory scientists (2), public health practitioners (2) and surveillance officials (2).
14 15	181	Identified themes mapped to the CFIR (Figure 1) demonstrate barriers across all parts of the
16 17 18	182	system including the poor fit between current technologies and adopting context. Features
19 20	183	likely to address these barriers (Figure 2) are also identified, providing viable design and
21 22 23	184	implementation approaches. These are further described and supported by selected
23 24 25	185	quotations from participants below.
26 27 28 29	186	Current practices and challenges
30 31	187	Diagnosis of dengue: Participants described how individuals with dengue may seek
32 33 34	188	healthcare at different types of healthcare facility, including primary health centres, district
35 36	189	hospitals, regional hospitals, referral hospitals, pharmacies or private clinics, with each type
37 38 39	190	having different clinical workforce and diagnostic test availability. There is a lack of
40 41	191	diagnostic testing in many rural and remote settings.
42 43 44 45	192	
46 47	193	"It depends on the level of [healthcare facility], if located in a very remote area, they cannot
48 49 50	194	do a blood test."
51 52 53	195	- Participant 6, Laboratory Scientist. Focus group 2.
53 54 55 56 57 58 59 60	196	
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Senior doctors described frequently diagnosing dengue based on clinical features and many

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> 8 said they often did not use a diagnostic test. 99 00 "I think the senior doctors like me are very used to following the clinical, but I think the new)1 generation of doctors are more likely to use the [RDT]." Participant 13, Doctor (Paediatrics). Focus group 3.)2)3 Cited reasons for not testing included a high degree of confidence in clinical diagnoses,)4)5 potentially inaccurate tests, and resource wasting. Some reported only using tests in atypical cases or outside dengue season.)6)7 When tests are used, RDTs are operated at laboratories or 'mini laboratories' (non-clinical 8(areas attached to smaller healthcare facilities), by a laboratory scientist, or sometimes at the point-of-care by a nurse. RT-PCR is rarely used because samples (or patients)9 0 themselves) must be transported to specialist laboratories and results may be delayed. .1 **Case reporting and information transfer:** Participants described a system of passive disease .2 surveillance requiring multiple stages of information transfer. Typically, diagnosed cases of .3 dengue are communicated to an individual with responsibility for disease reporting at a .4 health facility. Information is then transferred sequentially to local, regional and national levels of the surveillance system (figure 3).[31] This can be written on paper forms which are .5 transferred manually between individuals and departments. .6 .7

2 3		
5 4 5	218	<figure 3="" here=""></figure>
6 7 8	219	
9 10 11	220	This information transfer could be incomplete or delayed, potentially by up to 4 weeks, due
12 13	221	to laborious data input procedures, frequent duplication of tasks and lack of time- and
14 15 16	222	resource- allocation for these activities.
17 18 19	223	
20 21 22	224	"Oh I'm really sad to tell you, not only do we have an underdiagnosis situation, but we
23 24 25	225	have an underreporting situation also."
26 27 28	226	- Participant 17, Senior Surveillance Official. Focus group 4.
29 30 31	227	
32 33 34	228	"One of the reasons they don't report is they have to sit down and key in the result."
35 36 37	229	- Participant 18, Surveillance Official. Focus group 4.
38 39 40	230	
41 42 43	231	Some participants also described a parallel sentinel site surveillance system, with samples
44 45 46	232	undergoing serotype-specific testing at a central location. However, only low numbers of
47 48	233	cases are included, these are not recruited systematically, and batch-testing results in
49 50 51	234	availability of serotype data being delayed.
52 53 54	235	Use of surveillance data: When participants were asked about the benefits of case-
54 55 56	236	reporting, responses varied according to professional occupation. Doctors, nurses and
57 58 59 60	237	laboratory scientists did not identify benefits from this activity and were unaware of

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3 4	238	downstream processes . They rarely received epidemiological information or warning about
5 6 7	239	outbreaks as a result participation in surveillance.

"No one tells us, we just know when a large number of patients is coming!"

Participant 13, Doctor (Paediatrics). Focus group 3.

Public health practitioners and surveillance officials explained how national and regional

data is collated into reports but agreed that information could be disseminated more rapidly

and used more efficiently locally.

Requirements for new diagnostics in surveillance

Use setting and operator skillset: Participants stated that new devices for the diagnosis of

dengue should be usable in a wide range of settings, including at the point-of-care (inpatient

and outpatient) and in laboratories and 'mini laboratories'. There was a preference for

analysing a small volume (up to 4 drops, ~140uL) of capillary blood, obtainable by finger-

prick and transferred directly into the device.

> "If we use it in outpatients where there are many patients, obtaining blood from the

fingertip would be suitable"

Participant 14, Nurse (Inpatient). Focus group 3.

2		
3 4	259	There was a strong desire for minimal sample processing prior to analysis (i.e.
5	• • •	
6 7	260	centrifugation, pipetting, mixing or addition of reagents). This was frequently explained by
8	261	reference to currently available RDTs, which are simple to use.
9	201	reference to currently available fibro, which are simple to use.
10 11		
12	262	
13		
14	263	"Nurses are not using pipette. If that's needed, it needs to be in the lab."
15 16		
17	• • •	
18	264	 Participant 7, Nurse Assistant (Outpatients). Focus group 2.
19		
20 21	265	
22		
23	• • •	
24	266	"We have to try to mimic the [RDTs]"
25 26		
20 27	267	- Participant 3, Dengue Researcher. Focus group 1.
28		
29	200	
30 31	268	
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33	269	Diagnostic targets: Many participants stated that new diagnostic devices should have the
34 25		
35 36	270	ability to serotype infections. Public health practitioners, surveillance officials and several
37		
38	271	dengue researchers had particularly strong desires for this, noting that it has not been
39		
40 41	272	achieved by currently available RDTs.
42		
43	273	
44 45	270	
45 46		
47	274	<i>"If we can get the serotype in real-time of course it will make our control measures more</i>
48		
49 50	275	effective."
50 51		
52	276	- Participant 19, Surveillance Official. Focus group 4.
53	_	
54 55		
55 56	277	
57		
58	278	Doctors and nurses could also understand this potential surveillance benefit but stated that
59 60	270	
60	279	serotypes are of little consequence for individual patient management.

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3	280	
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6 7	281	Assay performance characteristics and implications for clinical and public health
, 8		
9	282	management of dengue: Most participants cited 'accuracy' as an important characteristic.
10		
11 12	283	They recognised that existing dengue tests sometimes had low sensitivity, which could
12		
14	284	affect patient management as well as surveillance. Low sensitivity tests which give falsely
15		
16	285	negative results may lead missed diagnoses of dengue, with further testing and treatments
17 18		
19	286	for other causes (for example bacterial infections) being initiated or continued
20		
21	287	unnecessarily.
22 23		
25 24	288	
25	200	
26		
27	289	"If the doctors see that the test is negative, [they] might diagnose something else and treat
28 29		
30	290	something else, like bacterial infection [this] might harm the patient."
31		
32	201	Dertisinent 10. Dester (Internel Medicine) Feeus group 4
33 34	291	 Participant 10, Doctor (Internal Medicine). Focus group 4.
35		
36	292	
37		
38 39	293	They suggested that new devices should have at least the same sensitivity as currently
40	293	They suggested that new devices should have at least the same sensitivity as currently
41	294	available RDTs.
42	294	available RDTS.
43 44		
44 45	295	Participants also recognised that non-specific tests could lead to alternative diagnoses being
46		
47	296	missed and discontinuation of important treatments (for example antibiotics).
48		
49 50	207	
51	297	
52		
53	298	<i>"If it has false positive it may lead to mistreatment of other diseases"</i>
54 55		
56	200	Darticipant 16 Dector (Internal Madicina) Facus group 2
57	299	- Participant 16, Doctor (Internal Medicine). Focus group 3.
58		
59 60	300	
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2		
3 4	301	"This means it's not dengue but something else. Yes definitely, this delays the treatment.
5 6 7	302	Yes it's going to be a problem."
8 9 10	303	- Participant 10, Doctor (Internal Medicine). Focus group 4.
11 12 13 14	304	
15 16	305	They caveated this by suggesting that users would become familiar with the performance of
17 18	306	any new test, and would interpret results accordingly. They also described how clinical and
19 20 21	307	epidemiological context are considered, when interpreting dengue test results.
22 23 24 25	308	
26 27	309	"We use it along with [routine laboratory data]. If [the test] is negative, but the case is likely
28 29 30	310	to be dengue, we still have [routine laboratory data] to follow-up the patient"
31 32 33	311	- Participant 16, Doctor (Internal Medicine). Focus group 3.
34 35 36 37	312	
37 38 39	313	<i>"If the local prevalence of the infection is high, then the test-negative will not ensure that the</i>
40 41	314	patient has no dengue infection. But if the patient is in a without dengue area, we will have
42 43 44	315	high confidence that this patient does not have dengue infection. It will depend on the
45 46 47	316	prevalence at the time and in the local area."
48 49 50	317	- Participant 16, Doctor (Internal Medicine). Focus group 3.
51 52 53	318	
54 55	319	Many participants also cited 'fast result' as an important characteristic. This was particularly
56 57 58 59 60	320	important for nurses and laboratory scientists who are frequent operators of RDTs. They

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suggested target sample-to-result time should be below one hour (and ideally below 15-20 minutes).

The 'ability to quantify virus' was not considered an important characteristic, either for clinical or surveillance purposes. However, some participants acknowledged potential utility in clinical research, for example in trials of antiviral mediations.

Connectivity and metadata: Participants recommended that diagnostic devices should have a simple way of displaying results to users with low chance of misinterpretation. They also stated that results should be recorded permanently on a patient's record. This could be achieved by integrating devices with electronic patient records and/or laboratory information systems, or by allowing results to be printed. There was agreement among all participants that integrating diagnostic devices with surveillance systems could be helpful, and that receiving serotype data would support surveillance efforts. Many suggested that it would reduce requirements for informal communication, paper records, data input and duplication of work at several levels of the surveillance system, hence improving case reporting. Public health practitioners and surveillance officials detailed which metadata should be reported routinely alongside the test results (Table 2). They also felt that optional reporting of pertinent clinical details could be useful (for example details of particularly severe or atypical cases which may warrant

<Table 2 here>

further investigation).

343	
344	As well as performing automated case notification ('upwards data transfer'), participants
345	suggested that a new diagnostic device could also receive and display epidemiological data
346	to the user ('downwards data transfer'). They expressed their desires for up-to-date
347	information about the numbers and severity of dengue cases in their area and agreed that
348	devices which provide early warning of dengue outbreaks would be useful.
349	
350	"If we know the information about the outbreak of dengue cases in the surrounding area, we
351	will be more aware of the possibility of more severe cases coming to the hospital"
352	- Participant 13, Doctor (Paediatrics). Focus group 3.
353	
354	Some explained how this knowledge could be used to assist in the interpretation of the
355	dengue test itself.
356	
357	"When patients present with fever during the outbreak season the clinician usually ask
358	where they come from. If we know that they come from an outbreak area, it increases the
359	possibility that the case may be dengue"
360	- Participant 13, Doctor (Paediatrics). Focus group 3.
361	
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3 4	362	However, some participants had concerns relating to data security, particularly if devices
5 6 7	363	could receive, store or display potentially sensitive information about other cases in the
, 8 9	364	region (for example their location).
10 11 12 13	365	
14 15	366	"Someone can think about stigmatisation. OK so this family has dengue and someone can
16 17 18	367	think that they are spreading dengue to the village, or something like that."
19 20 21	368	- Participant 10, Doctor (Internal Medicine). Focus group 2.
22 23 24	369	
25 26 27	370	Cost: Participants emphasised the importance of cost when considering the potential
28 29	371	introduction of new diagnostic devices in Thailand. Usually, diagnostic testing is paid for by
30 31 32	372	government insurance coverage, private insurance, or personal funds. Many participants
33 34	373	considered a conceptual difference between testing which is undertaken for individual
35 36 37	374	patient benefit (i.e. for diagnostic purposes) and that which is undertaken for potential
38 39	375	collective population benefit (i.e. for surveillance), and felt that using personal funds to pay
40 41 42	376	for the latter would be unfair.
43 44 45	377	for the latter would be unfair.
46 47 48	378	DISCUSSION
49 50 51	379	Participants in this study identified the need and potential value of new tests for dengue
52 53	380	which are accurate, rapid, low cost and can be operated easily by non-expert users outside
54 55 56	381	laboratory settings, including in remote and rural areas. They supported integration of
57 58	382	diagnostic devices with surveillance systems to increase quantity and speed of case-
59 60	383	notification. These requirements align with The World Health Organization (WHO) Special
		20

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1 2

2 3 4	384	Program for Research and Training in Tropical Diseases 'ASSURED' criteria for diagnostics,
5 6 7	385	and subsequent publications supporting real-time connectivity ('REASSURED'
7 8 9	386	characteristics). [32], [33], [34] Tests which can serotype may be important for surveillance
10 11	387	but are less likely to benefit individual patients. 'Upwards data transfer' (such that cases are
12 13 14	388	easily or automatically notified by users via devices to the surveillance authority), as well as
15 16	389	'downwards data transfer' (such that local case data and outbreak information is returned
17 18 19	390	to users) were considered useful potential functions. The latter would assist in
20 21	391	interpretation of individual test results and could give early warning of outbreaks. It is likely
22 23 24	392	that individual devices would individually connect with a cloud where data is stored and
25 26	393	analysed, and that this would be hosted by the local surveillance authority. Cautions
27 28 29	394	relating to this overall approach included data security and the potential cost when
30 31	395	compared to currently available diagnostic tests. Additionally, remote-connected devices
32 33 34	396	which transmit and receive data may become complicated to use, potentially affecting
34 35 36	397	uptake. Participants in this survey had a strong preference for diagnostics which are simple
37 38	398	to use. Therefore, prospective technology users should be engaged and involved in design,
39 40 41	399	and care must be taken to maintain simplicity and usability of devices for their primary
42 43	400	purpose of dengue diagnosis.
44 45 46	401	Previous studies have explored healthcare workers' and community members' perceptions
47 48	402	of new diagnostic devices for tropical infections, particularly those intended to be used at
49 50 51	403	the point-of-care. Diggle et al investigated malaria RDTs in Northern Kenya and found
52 53	404	significant knowledge gaps, misconceptions and evidence of low uptake. Reasons included
54 55 56	405	perceptions that testing was unnecessary, distrust of results, fear that devices might also
57 58	406	test for other, potentially stigmatised conditions, and cost. However, RDTs were noted for
59 60	407	their ease of use and portability.[21] Rasti et al investigated Southwestern Ugandan

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408	healthcare workers who described point-of-care tests improving diagnosis and clinical
409	decision making in under-resourced areas. However, they also reported experiencing
410	inaccurate results and a need to interpret and corroborate results with other clinical
411	information.[23] Boadu et al identified influencers of malaria RDT implementation among
412	primary healthcare providers in central Ghana. These included healthcare delivery
413	constraints, provider perceptions and social dynamics of care delivery.[20] A scoping review
414	of the use of mobile phones in the prevention and control of arboviral infections identified
415	six studies where mobile phone technology formed part of a diagnostic workflow, and 25
416	studies where mobile telephones were used in various surveillance activities.[35] Cited
417	benefits were a 'reduction in error of transcribed data', 'rapid data transfer', and 'good
418	completeness in terms of more dengue case reporting', which are highly relatable to the
419	present study's findings.[35] Another recent article has reviewed various digital health
420	interventions which have been used in dengue surveillance.[36]
421	This study is the first to specifically investigate user requirements for diagnostic devices that
421 422	This study is the first to specifically investigate user requirements for diagnostic devices that would optimise dengue surveillance. It collected data from a wide range of diagnostic
422	would optimise dengue surveillance. It collected data from a wide range of diagnostic
422 423	would optimise dengue surveillance. It collected data from a wide range of diagnostic technology users, including those who make decisions to test, those with hands-on
422 423 424	would optimise dengue surveillance. It collected data from a wide range of diagnostic technology users, including those who make decisions to test, those with hands-on experience of operating tests, and those who are involved in downstream analysis and
422 423 424 425	would optimise dengue surveillance. It collected data from a wide range of diagnostic technology users, including those who make decisions to test, those with hands-on experience of operating tests, and those who are involved in downstream analysis and usage of data. Broad inclusion appears to have been important because user requirements
422 423 424 425 426	would optimise dengue surveillance. It collected data from a wide range of diagnostic technology users, including those who make decisions to test, those with hands-on experience of operating tests, and those who are involved in downstream analysis and usage of data. Broad inclusion appears to have been important because user requirements sometimes varied between occupational groups. Innovation in technology should account
422 423 424 425 426 427	would optimise dengue surveillance. It collected data from a wide range of diagnostic technology users, including those who make decisions to test, those with hands-on experience of operating tests, and those who are involved in downstream analysis and usage of data. Broad inclusion appears to have been important because user requirements sometimes varied between occupational groups. Innovation in technology should account for this and may need to balance priorities of different users.

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431	appear similar to those experienced in other Southeast Asian nations[9] and more
432	widely.[13] Additionally, it did not include patients or members of the general public, who
433	are important users of diagnostic technology. In Thailand, there has been rapid increase in
434	the use of mobile phone technology, including for storage and sharing of personal health
435	records.[37], [38] Results from the present study highlight further need to engage this
436	group, particularly around the importance of data security. Furthermore, this study
437	focussed on dengue, but there is likely to be significant overlap in the experiences and
438	requirements of individuals who undertake surveillance of other arboviruses and other
439	infectious disease more generally. Surveillance requirements for devices which may
440	simultaneously detect multiple relevant pathogens should also be investigated, as
441	diagnostic technology advances.
442	Dengue is a major public health concern across tropical regions. Accurate, serotype-specific,
443	remote-connected diagnostic devices which can be used in a diverse range of settings would
444	enhance surveillance and could support real-time outbreak risk-assessment and warning.
445	These should be developed in collaboration with a range of prospective technology users.
446	
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449	their time and shared their experiences.
450	
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10 11 12	455	(RED) program, Faculty of Medicine Siriraj Hospital, Mahidol University.
13 14 15 16	456	
17 18 19	457	COMPETING INTERESTS
20 21 22	458	All authors declare that there are no competing interests.
23 24 25	459	
26 27 28	460	AUTHOR CONTRIBUTIONS
29 30 31	461	PArkell, SK, AS, DM, RA and SL designed the study. PArkell, SK and SL collected data. PArkell
32 33	462	and SK analysed data and drafted the manuscript. JR, PG, PM, PAvirutnan and AH were
34 35 36	463	awarded funding to collaborate and undertake a programme of dengue diagnostics
30 37 38	464	development which includes this qualitative work. All authors critically appraised the
39 40	465	manuscript and agreed to its submission for publication. PA is responsible for the overall
41 42 43	466	content. PA is the corresponding author and attests that all listed authors meet authorship
44 45 46	467	criteria and that no others meeting the criteria have been omitted. PA is the guarantor.
47 48 49	468	
50 51 52	469	DATA AVAILABILITY
53 54	470	Data are available upon reasonable request to PA, subject to an appropriate data sharing
55 56 57 58	471	agreement being implemented.
59 60	472	

2 3 4 5	473	FIGURE CAPTIONS
6 7 8	474	Figure 1
9 10 11	475	Identified themes within 'current practices and challenges relating to dengue diagnosis and
12 13	476	surveillance' mapped to the Consolidated Framework for Implementation Research (CFIR)
14 15 16	477	domains. Inner figure reproduced with permission from the original open access
17 18 19	478	publication, available at: https://cfirguide.org/cfirdiagram/.
20 21 22	479	Figure 2
23 24	480	Identified themes within 'requirements for new diagnostics' mapped to the Consolidated
25 26 27	481	Framework for Implementation Research (CFIR) domains. Inner figure reproduced with
28 29	482	permission from the original open access publication, available at:
30 31 32	483	https://cfirguide.org/cfirdiagram/.
33 34 35	484	Figure 3
36 37 38	485	Schematic diagram showing current, multi-level transfer of information in a passive dengue
39 40	486	surveillance system. Information is predominantly transferred 'upwards', with limited
41 42 43	487	'downwards data transfer' to communities and users.
44 45 46	488	
47 48 49	489	ETHICS APPROVAL
50 51 52	490	Potential participants received verbal and written information about the proposed study
53 54	491	purpose and its procedures. All participants provided written informed consent. This study
55 56 57	492	received ethical approval from Mahidol University Faculty of Tropical Medicine Research
58 59 60	493	Ethics Committee (MUTM-2022-031-01)

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634 Table 1: Focus group topic guide

Tabl	C I.	rocus group topic guide
	Α.	Contextual understanding and needs assessment.
	-	How is dengue surveillance done, at your workplace (and more broadly)?
	-	Where do patients present to with symptoms of dengue and how do they get diagnosed?
	-	If tests are not always done, why do you think this is?
	-	Where / how should cases of dengue get reported, to surveillance?
	-	If positive results are not always reported, why do you think this is?
	-	How are surveillance data used?
	В.	Requirements for new diagnostic devices: The assay.
	-	Where does diagnostic testing usually occur, and what laboratory equipment is available there (if any)?
	-	Who typically operates diagnostic devices, and what sample preparation / analysis skills do they have (if any)?
	-	What do you think would be the preferred sample type and sample volume, that would go into any new diagnostic device?
	-	What do you think would be the preferred (and maximum) time from sample to result (i.e. test duration), of any new diagnostic device?
	-	What do you think the preferred (and minimum) sensitivity and specificity, of any new diagnostic device?
	-	Is knowing the dengue serotype important?
	-	Is knowing the quantity of dengue (level of 'viraemia') in a patient's sample important?
	C.	Requirements for new diagnostic devices: Remote connectivity and reporting.
	-	How are results from diagnostic tests generally reported, and where are they stored?
	-	If a new diagnostic device could be remote-connected, where should results be reported to?
	-	Which information about cases would be most useful to report alongside test results, to enhance dengue surveillance?
	-	Would it be useful if a new diagnostic device could receive and display real-time information about local dengue incidence to the user (as well as transmitting data for case-reporting)?
L		

37	Table 2: Basic metadata requirements for automated case-reporting within the Thai surveillance
38	system.
	Upwards data transfer (device to surveillance system)
	A. Test-related data
	- Date of test (date)
	- Geo-location of test (lat, long)
	- Dengue test result (positive/negative)
	- Serotype result (DENV1/DENV2/DENV3/DENV4)
	B. Identifiers
	- Name (free text)
	- National ID (number)
	- Home address (free text)
	- Patient's (or parent/guardian's) telephone number (number)
	C. Clinical details
	- Duration of symptoms in days (number)
	 Severity of case at time of testing if dengue suspected clinically (non-severe/dengue with
	warning signs/severe dengue/patient died)
	 Alternative clinical diagnos(es), if applicable (free text)
	- Additional information for communication to surveillance authority. For example, detail
	of particularly severe or atypical cases, or those where multiple family members are
	unwell, which may warrant further investigation (free text)
	Downwards data transfer (surveillance system to device)
	- All test-related data (see A, above) from other devices.*
39 40 41 42	* These data could be output to the clinical user as individual cases (for example displayed on a map), or after aggregation and/or analysis in the form of an epidemiological report.

Current practices and challen

Diagnosis of dengue Use of RDTs (less accurate, do not serotype) RT-PCR assays for serotyping at sentinel sites only 10

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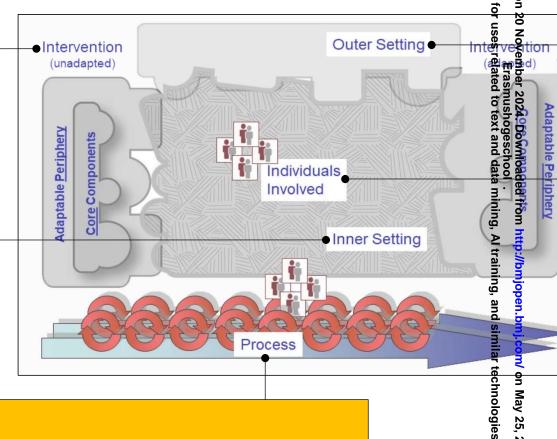
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12 **Diagnosis of dengue** 13 14 Clinicians often diagnose 15 dengue clinically 16 (Do not use tests because they 17 may not be useful and are 18 considered wasteful, unless 19 20 atypical/outside season) 21



Diagnosis of dengue

Batch testing causes delays

Case reporting and info transfer

Passive surveillance requires multiple stages of information transfer Additional parallel sentinel site surveillance for serotyping, but lack of systematic sampling

Laborious data input procedures and duplication of tasks

Lack of resource allocation for surveillance tasks

Use of surveillance data

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Lack of timely dissemination of case data locally

Doctors request test, laboratory personnel or nurses conduct testing

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at Department GEZ-

Case reporting and information transfer

Health seeking at different types of healthcare

Testing infrastructure not available in rural and

Available clinical workforce depends on health

(Laboratory and/or transport infrastructure)

Multiple individuals at various administrative levels report cases and analyse data

Use of surveillance data

Diagnosis of dengue

Diagnosis of dengue

remote settings

facility

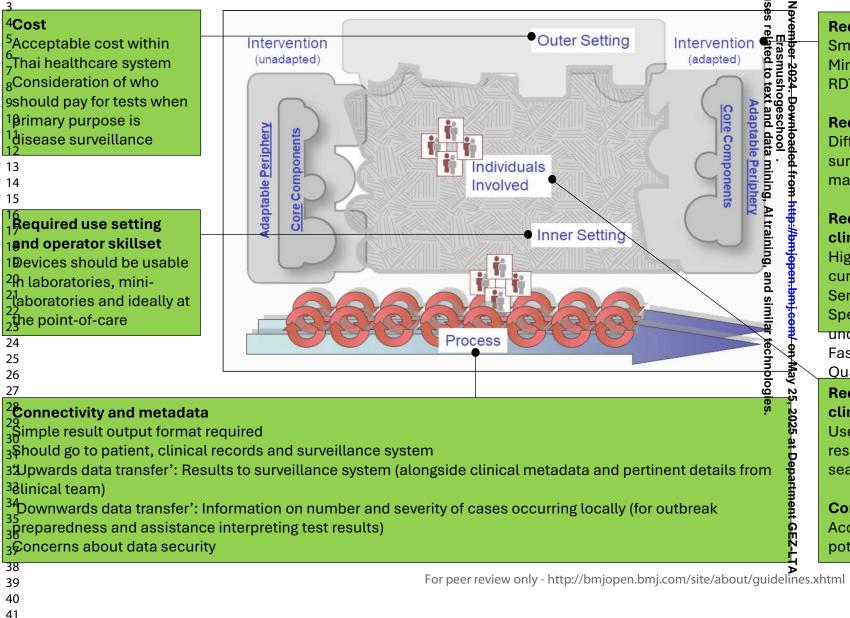
facility

Surveillance officials collate and analyse data Doctors, nurses and lab scientists unaware of processes and don't use data

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Requirements for new diagnostics in street ance



Required use setting and operator skillset

Small volume (140uL) of whole capillary blood Minimal sample processing (similar to currently available RDTs)

Required diagnostic targets

Differentiation of dengue virus serotypes important for surveillance and research (but not for clinical case management)

Required performance characteristics and implications for clinical and public health management of dengue

High accuracy at all disease stages (at least comparable to currently available RDTs)

Sensitive such that cases are not missed

Specific so other diagnoses are not overlooked and

undertreated

Fast time-to-result (less than 1 hour)

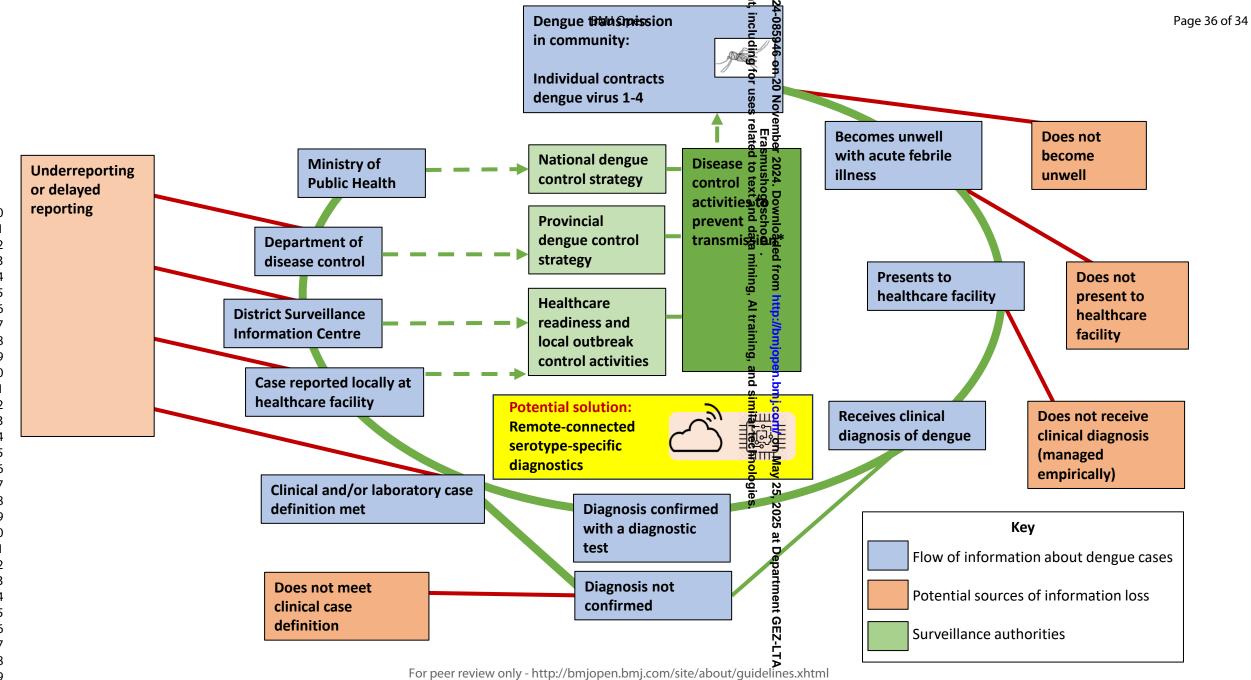
Ouantification of virus may be important in research

Required performance characteristics and implications for clinical and public health management of dengue

Users become familiar with performance of tests and interpret results accordingly (alongside other data, and according to seasonality of dengue transmission)

Connectivity and metadata

Acceptability of data sharing to patients and their families, potential for stigma



* Current disease control activities comprise environmental management and insecticide use. Future activities may also include deployment of vaccines and Wolbachia-infected mosquitos.