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Frequencies and patterns of microbiology test requests from primary care in Oxfordshire, UK, 2008–2018: a retrospective cohort study of electronic health records to inform point-of-care testing

JM Ordóñez-Mena ,[1,2] Thomas R Fanshawe,[1] Dona Foster,[3] Monique Andersson,[4] Sarah Oakley,[4] Nicole Stoesser,[2,3,4] A. Sarah Walker,[2] Gail Hayward [1]

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For numbered affiliations see end of article.

Correspondence to
Dr JM Ordóñez-Mena; jose.ordonezmena@phc.ox.ac.uk

ABSTRACT

Objectives To inform point-of-care test (POCT) development, we quantified the primary care demand for laboratory microbiology tests by describing their frequencies overall, frequencies of positives, most common organisms identified, temporal trends in testing and patterns of cotesting on the same and subsequent dates.

Design Retrospective cohort study.

Setting Primary care practices in Oxfordshire.

Participants 393 905 patients (65% female; 49% aged 18–49).

Primary and secondary outcome measures The frequencies of all microbiology tests requested between 2008 and 2018 were quantified. Patterns of cotesting were investigated with heat maps. All analyses were done overall, by sex and age categories.

Results 1 596 752 microbiology tests were requested. Urine culture±microscopy was the most common of all tests (n=673 612, 42%), was mainly requested without other tests and was the most common test requested in follow-up within 7 and 14 days. Of all urine cultures, 180 047 (27%) were positive and 172 651 (26%) showed mixed growth, and *Escherichia coli* was the most prevalent organism (132 277, 73% of positive urine cultures). Antenatal urine cultures and blood tests in pregnancy (hepatitis B, HIV and syphilis) formed a common test combination, consistent with their use in antenatal screening.

Conclusions The greatest burden of microbiology testing in primary care is attributable to urine culture ± microscopy; genital and routine antenatal urine and blood testing are also significant contributors. Further research should focus on the feasibility and impact of POCTs for these specimen types.

Strengths and limitations of this study

- ► We analysed a very comprehensive dataset with detailed data for all microbiology test requests and results over a decade by a large clinical microbiology laboratory.
- ► Coding of tests may have changed over time, but we reviewed 95% of all codes and grouped similar ones to avoid missing relevant tests.
- ► The results of our study may not apply to other regions of the UK or other countries, where patterns of testing and prevalence of organisms may differ.
- ► It was not always possible to distinguish between test combinations done together as a standard of practice by the laboratory from those that were requested together for clinical reasons.

INTRODUCTION

Viral, bacterial and parasitic infections are associated with a large burden of morbidity and mortality worldwide.[1 2] Rapid and accurate identification of pathogens causing the infection could lead to quicker selection of therapy, improve prognosis and reduce transmission. This may also facilitate antibiotic stewardship by ensuring antibiotics are only prescribed when appropriate.[3 4]

Near-patient or point-of-care (POC) tests are investigations carried out in clinical settings or the patient's home that provide a rapid result without depending on specialist laboratories, which can take hours to days to yield an outcome.[5] Technological advances and their potential benefits[3] have contributed to some POC tests becoming available in primary care,[5] despite doubts about their cost-effectiveness.[6]

In the UK, antimicrobial prescribing guidelines for primary care are produced locally and can occasionally also incorporate

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suggested diagnostics.[7] These change over time according to national and local changes in resistance and guidelines.

Due to limited resources and technical development in some cases, and also partly to the variability in specimens received by the laboratory (eg, urine, blood, stool, sputum), which guides the processing and culture medium needed, clinical microbiology continues to rely on traditional methods such as specimen-specific cultures to identify microorganisms.[8] In the last decade, molecular methods including PCR, microarray and nucleic acid sequencing have started to take a prominent place in clinical microbiology. There are examples of rapid tests for HIV,[9] hepatitis C,[10] influenza,[11] syphilis[12] and urinary tract infections.[13]

Multiplex tests that permit the identification of different pathogens in the same specimen are also now available.[14] For example, there are various multiplex molecular panels that can detect bacteria, viruses and parasites in stool samples.[15] In secondary care, BioFire FilmArray panels can be used to detect bacterial or viral pathogens and antimicrobial resistance genes when investigating respiratory tract infections.

Despite the potential advantages of POC testing in primary care, barriers to uptake include concerns about their clinical utility and technical performance, over-reliance on results, undermining of clinical skills and cost.[16] Identifying which individual tests and combinations are most frequently requested from primary care, as has already been noted for biochemistry laboratory blood tests,[17] could inform test development and adoption of POC tests by general practitioners (GPs). Although microbiology testing in primary care in the UK has been examined in terms of regional inequalities for a limited number of tests,[18] a comprehensive assessment of current demand for microbiology testing from primary care is currently lacking.

The aim of this study was to describe the frequencies of the most commonly requested microbiology tests, individually and in combination, from primary care practices in the publicly funded National Health Service Oxfordshire Clinical Commissioning Group.[19] We also explored the yearly usage of these tests and described the most common organisms identified in positive results.

METHODS

Study setting and population

The Oxford University Hospitals Microbiology laboratory processes all samples taken from primary care GP surgeries in Oxfordshire. We conducted a retrospective cohort study using the Infections in Oxfordshire Research Database (IORD), including all microbiology tests requested by 74 active and 20 closed/merged GP surgeries in Oxfordshire between January 2008 and May 2018.[20]

Test grouping

As our aim was to summarise frequently occurring tests, we decided to exclude infrequent tests which were requested less than 1000 times a year. This rule covered for 95% of all test codes. Some of the included tests may show a lower frequency due to elimination of duplicates and grouping of test codes. Tests routinely performed together as part of standard operating procedures were grouped (online supplemental table 1). For example, urine microscopy is reserved for few specific indications and usually accompanied by urine culture (but not necessarily vice versa), so formed a single category. Faecal test was similarly grouped.

This created eight groups of culture±microscopy test requests: urine, genital, surface swab, faecal, antenatal urine, dermatophyte, pus and respiratory tract. Gastrointestinal PCR bacterial panel tests (BD MAX Enteric Panel, Becton Dickinson, New Jersey, USA), for the identification of *Salmonella* spp, *Campylobacter* spp, *Shigella* spp, and shigatoxigenic *Escherichia coli* in faeces, were also grouped. Other tests targeted individual organisms/infections (online supplemental table 1). For each of hepatitis B, hepatitis C and HIV, serology and molecular tests (antigen, antibody, ±DNA or RNA) were grouped.

We excluded a small number of tests that are no longer routinely requested or tests misclassified as microbiological, such as semen analysis for male fertility.

Nearly all test codes (99%) were included, the remaining excluded due to being too infrequent. Results were classified as positive or negative, as appropriate for the test type. For example, a culture was considered positive if it met the laboratory standard defined in standard operating procedures (eg $>10^4$–10^5 CFUs/mL of a pathogenic organism in urine cultures); mixed growth and equivocal results were reported separately.

Statistical analysis

The frequency of the most common microbiology tests was described. We also reported the number of patients with at least one test during the study period, and the frequency of positive results. For each test, we reported the five the most common organisms identified, as percentages of the total number of tests and of the total number of positives.

Data were reported overall, by sex, and by age category. We used heat maps to investigate test combinations requested on the same date, and within 7 and 14 days after an initial request, since tests within this time period are more likely to be requested for the same medical condition. Statistical analyses were conducted in R (V.3.6.0) using the 'ComplexHeatmap' package.[21]

Patient and public involvement

Patients and the public were not involved in the design, conduct or reporting of this research.

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Table 1 Frequency of microbiology tests requested by primary care surgeries in Oxfordshire between 2008 and 2018

	Tests		Test results			Patients	
Test group	N	%	Positive*	Mixed growth	Equivocal	N	%†
All tests	1 596 752	100				393 905	100
Culture±microscopy							
Urine	673 612	42.2	26.7	25.6	3.05	247 356	62.8
Genital	108 861	6.82	27.8	–	–	69 055	17.5
Surface swab	68 288	4.28	41.1	–	–	48 854	12.4
Faecal	68 240	4.27	9.74	–	–	55 032	14.0
Antenatal urine	57 423	3.60	6.57	25.4	1.79	37 923	9.63
Dermatophyte	24 093	1.51	26.8	–	–	21 029	5.34
Pus	4933	0.31	35.0	3.26	–	4332	1.10
Respiratory tract	3211	0.20	93.6	–	–	1671	0.42
Tests targeting specific organisms			**Positive**				
Hepatitis B	116 366	7.29	Surface antigen: 0.59 (470/79811) antenatal, 3.15 (956/30359) non-antenatal			80 658	20.5
HIV	99 436	6.23	0.56			67 467	17.1
Treponema pallidum (syphilis)	84 686	5.30	0.06			58 002	14.7
Chlamydia	76 711	4.80	2.35			55 682	14.1
Rubella (antibody)	76 556	4.79	96.5			51 705	13.1
Helicobacter pylori	51 137	3.20	20.0			45 456	11.5
Hepatitis C	30 910	1.94	Antibody: 5.52 (1633/29561) RNA 51.3 (779/1519)			25 468	6.47
Cryptosporidium/Giardia	22 422	1.40	2.45			19 076	4.84
Clostridioides difficile	12 975	0.81	5.70			10 489	2.66
Gastrointestinal bacterial panel‡	10 015	0.63	15.6			9202	2.34
Epstein-Barr virus	6877	0.43	EBNA IgG: 70.5 (4649/6592) VCA IgG: 47.6 (1033/2172) VCA IgM: 26.6 (568/2136)			6570	1.67

*Positivity in cultures reflects the detection of one or more organisms in the specimen provided, and should not necessarily be interpreted as an indication of pathogenicity.
†Percentages may not add to total as patients could have more than a single test of a different type during the study period.
‡An enteric pathogen panel that tests for *Shigella* spp, *Salmonella* spp, *Campylobacter* spp and shiga toxin genes (for the detection of shigatoxigenic *Escherichia coli* such as O157).
EBNA, Epstein-Barr virus Nuclear Antigen; VCA, viral capsid antigen.

RESULTS

The dataset included 1 596 752 test requests (average 145 000/year), corresponding to 1 207 518 request dates among 393 905 patients. For comparison, the mid-2018 population estimate for Oxfordshire was 687 524.[22] Most patients were female (257 367, 65.3%), and the age distribution was similar to that of Oxfordshire (online supplemental table 2).

Frequencies of testing

Table 1 shows the frequencies of the most commonly requested test groups. Urine culture±microscopy was the most common (65 000 /year), accounting for 42% of tests and 63% of patients with at least one test during the study period. The most common targeted test was hepatitis B virus (11 000/year, primarily surface antigen tests) accounting for 7% of all tests and 20% of all patients. Respiratory tract cultures accounted only for 0.20% of all tests and 0.42% of all study participants.

Of all tests, 79% were from females, and among included patients, females had two times as many tests per person as males (mean 4.9 vs 2.5) (table 2), mainly due to more urine and genital cultures and antenatal tests in women aged 18–49. Conversely, surface swabs, faecal tests, dermatophyte, pus and respiratory tract cultures were the most common in males. Proportionally more urine and *Clostridioides difficile* tests were conducted in older individuals

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Table 2 Frequency of microbiology tests by sex in Oxfordshire primary care practices between 2008 and 2018

	Male				Female			
Test group	N tests	%	N patients	%*	N tests	%	N patients	%*
All tests	343020	100	136538	100	1253732	100	257367	100
Culture±microscopy								
Urine	171656	50.0	75460	55.3	501956	40.0	171896	66.8
Genital	648	0.19	600	0.44	108213	8.63	68455	26.6
Surface swab	28966	8.44	20511	15.0	39322	3.14	28343	11.0
Faecal	30594	8.92	25014	18.3	37646	3.00	30018	11.7
Antenatal urine	–	–	–	–	57415	–	37915	–
Dermatophyte	11278	3.29	9862	7.22	12815	1.02	11167	4.34
Pus	2566	0.75	2234	1.64	2367	0.19	2098	0.82
Respiratory tract	1337	0.39	751	0.55	1874	0.15	920	0.36
Tests targeting specific pathogens								
Hepatitis B	17952	5.23	15033	11.0	98414	7.85	65625	25.5
HIV	9418	2.75	7781	5.70	90018	7.18	59686	23.2
Treponema pallidum (syphilis)	1865	0.54	1739	1.27	82821	6.61	56263	21.9
Chlamydia	4655	1.36	4342	3.18	72056	5.75	51340	20.0
Rubella	353	0.10	342	0.25	76203	6.08	51363	20.0
Helicobacter pylori	21463	6.26	19354	14.2	29674	2.37	26102	10.1
Hepatitis C	16428	4.79	13489	9.88	14482	1.16	11979	4.65
Cryptosporidium/Giardia	11571	3.37	9751	7.14	10851	0.87	9325	3.62
Clostridioides difficile	5033	1.47	4117	3.02	7942	0.63	6372	2.48
Gastrointestinal bacterial panel†	4486	1.31	4146	3.04	5529	0.44	5056	1.96
Epstein-Barr virus	2743	0.80	2639	1.93	4134	0.33	3931	1.53

*Note these percentages may not add to the total as patients could have more than a single test of a different type during the study period.
†An enteric pathogen panel that tests for *Shigella* spp, *Salmonella* spp, *Campylobacter* spp and shiga toxin genes (for the detection of shigatoxigenic *Escherichia coli* such as O157).

(online supplemental table 3). *Cryptosporidium/Giardia* tests were done mostly in children aged 13 or younger. Respiratory tract cultures were more likely done in children aged 14–17 years, and in older adults.

Patterns of testing

Figure 1 shows combinations of tests requested on the same date. Urine tests were mainly requested in isolation. Antenatal tests were often requested in combination. Faecal culture±microscopy were often accompanied by *Cryptosporidium/Giardia*, *C. difficile* and gastrointestinal bacterial PCR tests. Many genital cultures were accompanied by a chlamydia PCR test.

Online supplemental figures 1–6 show test combination frequencies by age. In all age groups, urine culture±microscopy remained the most frequent request in isolation. Faecal culture±microscopy, *Cryptosporidium/Giardia*, gastrointestinal bacterial PCR and *C. difficile* tests were the most common combination in children aged 0–13. In children aged 14–17, genital culture±microscopy and chlamydia tests became more common. In the 50–64 age group, *Helicobacter pylori* was the second most common test. In the two oldest groups, surface swabs were the second most common test, and faecal tests, *Cryptosporidium/Giardia*, gastrointestinal bacterial and *C. difficile* formed the most common combination.

Overall, 18% (71 572/393 905) and 23% (91 483/393 905) of all patients were retested on 102 108 and 154 528 occasions within 7 and 14 days, respectively. Urine (including antenatal) tests were a common reason for retesting within 7 days, often in combination with rubella, hepatitis B, syphilis or HIV (figure 2). Of the gastrointestinal bacterial panel, 13% were followed by faecal culture or microscopy within 7 days. Similar patterns were seen for 14 days (online supplemental figure 7). Repeated testing more often followed a mixed growth result than a positive or negative result: 7% of mixed growth urine cultures were followed by a repeat urine culture test within 7 days, compared with 4% of positive and negative urine cultures.

Test results

Table 1 shows percentages of tests that yielded a positive result. Urine cultures were positive, mixed growth and equivocal in 27%, 26% and 3% of cases, respectively. Antenatal urine cultures were less often positive (7%) but mixed growth (25%) remained common. Positive results occurred more often for surface swabs (41%) and pus

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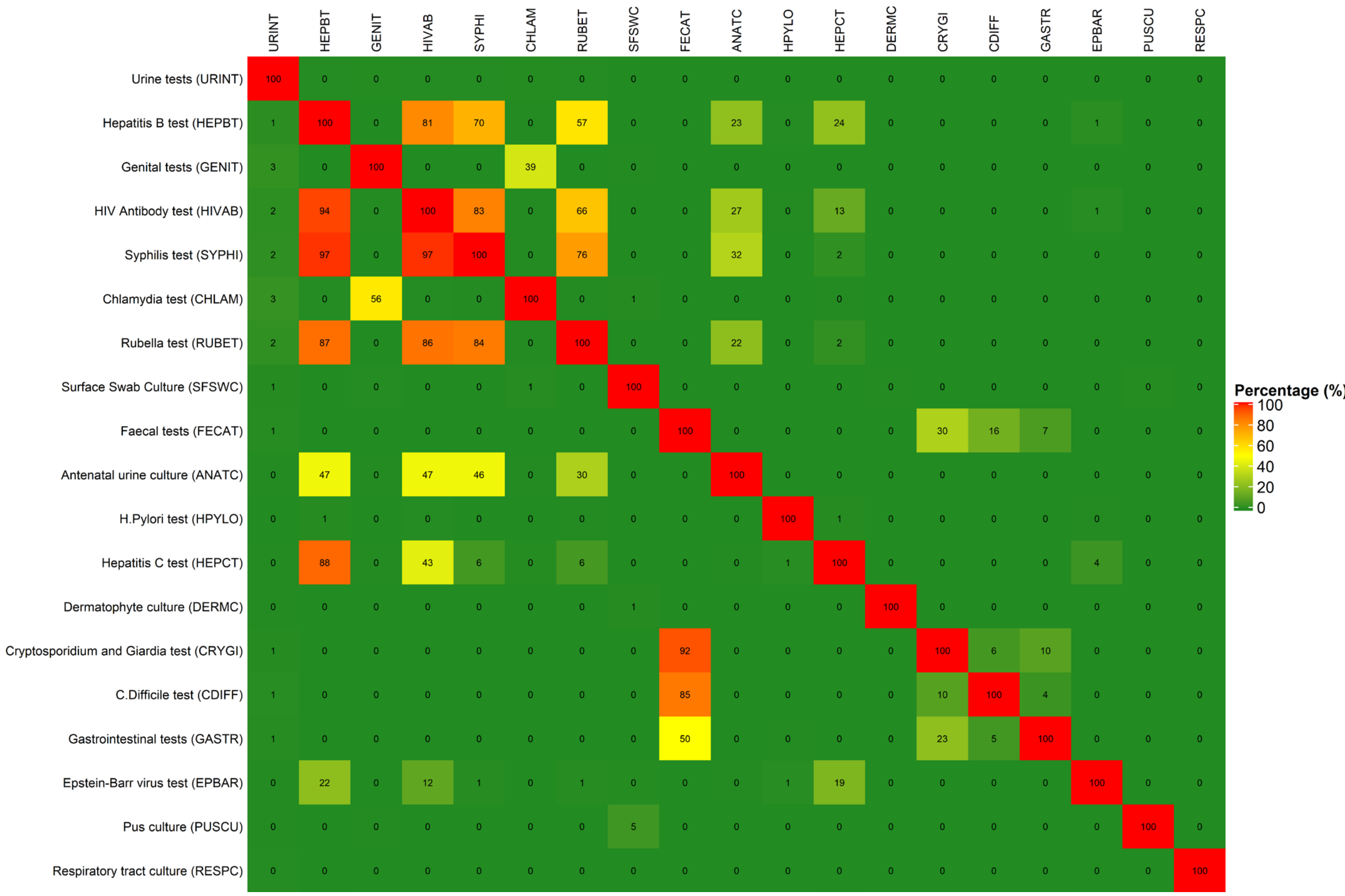

Figure 1 Heat map showing the percentage of all tests in the row that were also accompanied by the test in the column.

(35%) cultures. Most respiratory tract cultures were positive for at least one organism (94%).

The most common organism detected in urine culture was *E. coli*: 20% of all urine cultures, 73% of positive urine cultures and 48% of positive antenatal urine cultures (table 3). *Enterococcus* spp (primarily *Enterococcus faecalis*) were more common in positive antenatal urine cultures (33%) than in positive general urine cultures (7%). Particular organisms predominated in other groups: *Candida* spp in 72% of positive genital cultures, *Staphylococcus* spp in 60% of positive surface swab cultures and 62% of positive pus cultures, *Campylobacter* spp in 85% of positive faecal cultures, and *Trichophyton* spp in 89% of positive dermatophyte cultures.

Urine cultures were more likely to return positive results in females than in males (29% vs 20%), while positive dermatophyte cultures were more common in males (32%) than in females (22%) (online supplemental table 4). Urine cultures were more often positive in older individuals, and *Proteus* spp were more common in children and older adults (online supplemental tables 5 and 6). In surface swab cultures, *Staphylococcus* spp prevalence increased with age. In dermatophyte cultures, *Trichophyton* spp became less prevalent and *Candida* spp more prevalent with increasing age.

Most serological tests performed in the antenatal screen returned negative results; for example, hepatitis B surface antigen was detected in 0.6% of samples, and 96% were positive for rubella antibodies, consistent with previous vaccination/infection (table 1). Among non-antenatal serological tests, *H. pylori* antibodies were detected in 20% of samples. Of the Epstein-Barr virus group, 71% were positive for Epstein-Barr virus Nuclear Antigen (EBNA) IgG (suggesting previous exposure), 48% for Viral Capsid Antigen (VCA) IgG and 27% for VCA IgM (consistent with acute infection). Positive results for *H. pylori* and Epstein-Barr virus were more common at older ages (online supplemental table 6). For non-culture faecal investigations, positive results occurred in 16% of gastrointestinal PCR tests, 6% of *C. difficile* tests and 2% of *Cryptosporidium/Giardia* tests.

Longitudinal trends in testing

For most tests, the number of requests per year remained roughly constant over time (online supplemental figures 8 and 9). Antenatal urine requests increased between 2008 and 2011 in line with the National Institute for Health and Care Excellence (NICE) guidance to offer women screening for asymptomatic bacteriuria early in pregnancy to reduce the risk of pyelonephritis.[23] Genital testing declined slightly after 2015 as swabs without specific clinical indication are no longer recommended in the NICE guidance.[24] Rubella IgG and *C. difficile* tests have decreased, as NICE guidelines did not advocate

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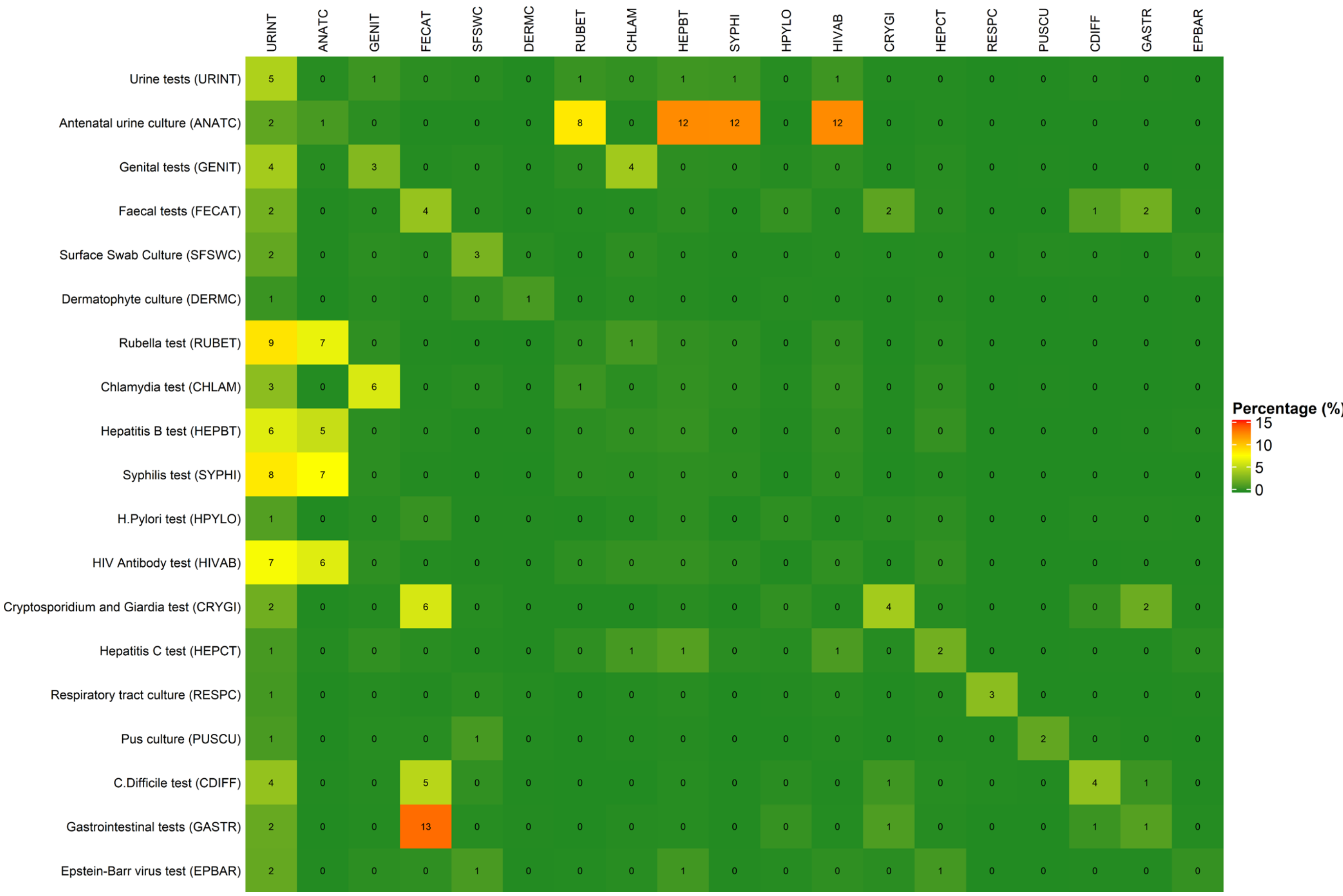

Figure 2 Heat map showing the percentage of all tests in the row that were followed by the test in the column within 7 days.

rubella screening in pregnancy after April 2016,[25] alongside a national decline in *C. difficile*-associated infection.[26] *H. pylori* testing has gradually increased, and gastrointestinal PCR tests were not conducted until 2016, when the BD MAX Enteric Bacterial Panel was introduced.

DISCUSSION

Summary of findings

In this analysis of microbiology testing patterns in primary care in Oxfordshire, we have shown that the greatest burden of testing is attributable to urine tests (42% of all tests). The burden was even greater in the older age groups (57%–81% of all tests in these age groups). This is understandable as NICE guidance recommends samples to be sent for urine cultures in women with suspected urinary tract infection if they are pregnant, are older than 65, had a positive urine dipstick or had symptoms persisting after antibiotic treatment.[7 27] Antenatal urine cultures and blood tests, which are part of national antenatal screening NICE guidelines,[28] are the second largest contributor, but are much less frequent (5%–7% of all tests) than urine cultures. Of note, 26% of all urine cultures were reported as mixed growth, consistent with poor sample quality reflecting perineal contamination.

Antenatal urine cultures were less likely to be positive (7%) than urine cultures in other individuals (27%), many of whom would be expected to be symptomatic. NICE guidance advocates treatment of asymptomatic bacteriuria in pregnancy as this may be a risk factor for pyelonephritis, low birth weight and premature delivery.[29] While *E. coli* was the predominant organism in positive urine cultures, the proportion containing *Enterococcus* spp or *Streptococcus* spp (predominantly Group B) was higher in antenatal cultures. Novel POC urine tests should therefore be capable of identifying a range of targets, including Group B streptococci in pregnant women.

For several tests, results may have reflected the prevalence of normal flora or sample contamination, so those classified as 'positive' were not necessarily pathogenic and may not have changed empiric management.[30 31] Examples include *Candida* spp in genital cultures and *Staphylococcus* spp in surface swab cultures. The apparent high positivity rate in respiratory tract cultures was caused by a range of organisms, of which some may be pathogenic but many may form part of the commensal microbiota.[30 32]

Among faecal specimens, positive culture results were less common overall (10% of faecal samples), with *Campylobacter* spp being the most common organism detected, consistent with national trends.[33] We observed gastrointestinal PCR tests and faecal cultures are often requested on the same and subsequent dates. Since 2016, the most

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Table 3 Frequency of the five most common organisms by test group in Oxfordshire primary care practices between 2008 and 2018

Test group organism detected	N positive*	% of positive specimens	% of all tested specimens
Urine	180 047	100	26.7
Escherichia coli	132 227	73.4	19.6
Enterococcus spp	13 093	7.27	1.94
Klebsiella spp	7050	3.92	1.05
Staphylococcus spp	6783	3.77	1.01
Proteus spp	6728	3.74	1.00
Other	14 177	7.87	2.10
Genital	30 270	100	27.8
Candida spp	21 767	71.9	20.0
Metronidazole-sensitive anaerobes	5316	17.6	4.88
Streptococcus spp	4421	14.6	4.06
Staphylococcus spp	676	2.23	0.62
E. coli	393	1.30	0.36
Other	41	0.14	0.04
Surface swab	28 029	100	41.0
Staphylococcus spp	16 798	59.9	24.6
Streptococcus spp	8495	30.3	12.4
Candida spp	3227	11.5	4.73
Metronidazole-sensitive anaerobes	1109	3.96	1.62
Haemophilus spp	1001	3.57	1.47
Other	797	2.84	1.17
Faecal	6649	100	9.74
Campylobacter spp	5631	84.7	8.25
Salmonella spp	608	9.14	0.89
Giardia lamblia	288	4.33	0.42
Shigella spp	83	1.25	0.12
E. coli	82	1.23	0.12
Other	4	0.06	0.01
Antenatal urine	3773	100	6.57
E. coli	1796	47.6	3.13
Enterococcus spp	1250	33.1	2.18
Streptococcus spp†	325	8.61	0.57
Staphylococcus spp	193	5.12	0.34
Candida spp	100	2.65	0.17
Other	109	2.89	0.19
Dermatophyte	6452	100	26.8
Trichophyton spp	5746	89.1	23.8
Candida spp	577	8.94	2.39
Fusarium spp	94	1.46	0.39
Acremonium spp	68	1.05	0.28
Scopulariopsis spp	44	0.68	0.18
Other	8	0.12	0.03
Pus	1725	100	35.0
Staphylococcus spp	1076	62.4	21.8
Streptococcus spp	295	17.1	5.98
Pseudomonas spp	186	10.8	3.77
E. coli	123	7.13	2.49
Metronidazole-sensitive anaerobes	100	5.80	2.03
Other	218	12.6	4.42
Respiratory tract	3004	100	93.6
Haemophilus spp	1203	40.0	37.5
Pseudomonas spp	880	29.3	27.4
Streptococcus spp	314	10.5	9.78
Staphylococcus spp	306	10.2	9.53
Moraxella spp	283	9.42	8.81
Other	358	11.9	11.1

*The number of tests positives for all organisms within a test group may not add up to the total number of positives, as some specimens may be positive for more than one organism.
†Predominantly Group B streptococcus.

common bacterial pathogens have been tested with PCR and if positive for *Shigella* spp, and/or shigatoxigenic *E. coli*, they are confirmed with faecal culture and reference laboratory testing. For *Salmonella* spp, a culture plate is usually set up in parallel with PCR.

In the UK, respiratory tract infections are a common reason for consultation in primary care[34] although are in most cases caused by a virus and do not need antibiotic prescription.[7] Guidelines recommend further investigation only if symptoms deteriorate or do not resolve after 3 weeks.[7] Respiratory tract cultures were very uncommon in our study, although commoner among males, in children aged 14–17 years, and in older adults. Respiratory tract cultures are requested by primary care doctors to assist in the diagnosis of rare respiratory conditions such as cystic fibrosis[35] or in the management of acute exacerbations of bronchiectasis[36] or chronic obstructive pulmonary disease.[37] Due to their being used significantly less than other culture types, they are unlikely to be a useful candidate for the development of new POC tests.

Strengths and limitations

The main advantage of our investigation is the availability of a comprehensive dataset including all microbiology test requests and results recorded over a decade by a large clinical microbiology service, minimising selection or sampling bias.

Our study has also limitations. First, test coding may have changed over time, but we reviewed 95% of all codes and grouped similar ones to avoid missing relevant tests. Second, as our study was done in a single county, we cannot extrapolate to other regions where patterns of

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testing and prevalence of organisms may differ.[18] Thirdly, it was not always possible to distinguish test combinations performed together by default from those which were requested together for clinical reasons, and therefore it is unclear which elements of, for example, faecal PCR would be a clinical priority. Relatedly, we cannot be certain whether some test groups were requested in response to symptoms or as part of routine management. The latter appears likely for the antenatal test group, as typically antenatal urine tests and hepatitis B, HIV and syphilis blood tests would be requested together at booking, and so if these appeared on different dates it may have been an artefact of how data are recorded or reporting delays. Finally, we have considered the demand from primary care to inform prioritisation of the development of new POC tests, but we could not consider the likely costs of these new POC tests, their acceptability by primary care doctors and patients and other factors relevant for their adoption.[16]

Comparison with other literature

A previous study investigated the demand for biochemistry laboratory blood tests in the community in Oxfordshire.[17] In comparison, microbiology tests form a smaller number of overall requests from primary care (approximately 145 000 per year vs 3.6 million per year), but microbiology tests were more frequently repeated within 7 days (18% vs less than 3% for most specific blood tests). This might be explained by the number of urine cultures that returned inconclusive or mixed growth results. The balance between total demand and the ability to perform rapid repeat testing should therefore be considered when setting priorities for POC test development. Consideration should also be given to improving sample quality for urine tests, whether performed at POC or in the laboratory.

Implications for research and practice

Our results suggest that tests targeting urine infection diagnostics should have high priority for POC test development, based on the high frequency of requests made. The figures presented here underestimate the likely demand for total number of urine investigations performed in primary care. Urine dipsticks taken at the point of care are more commonly used to diagnose urinary tract infection than urine cultures in the UK and other European countries.[38 39] This is particularly the case among non-pregnant and non-menopausal women. The diagnostic performance of urine dipsticks is inferior to bacteriological urine culture, which are often used to confirm positive urine dipsticks, and remain the 'gold standard' for investigating urinary tract infections.[40] Viable POC tests should be able to detect the range of organisms described here, and reduce the need for repeat testing, caused in part by mixed growth results. Further work should aim to assess factors that might affect uptake of such POC tests in practice, including cost-benefit considerations, as well as the clinical impact of tests becoming available.

Our analysis has also highlighted the potential value of a diagnostic for other specimen types that have a high burden of testing, notably genital samples and tests for antenatal screening.

Author affiliations
[1]Department of Primary Care Health Sciences, University of Oxford Nuffield, Oxford, UK
[2]NIHR Biomedical Research Centre, Oxford University Hospitals NHS Foundation Trust, Oxford, UK
[3]Nuffield Department of Medicine, University of Oxford, Oxford, UK
[4]Department of Microbiology, Oxford University Hospitals NHS Foundation Trust, Oxford, UK

Twitter JM Ordóñez-Mena @JMOM85, Nicole Stoesser @nicstoesser and Gail Hayward @gailhayward1

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ORCID iDs
JM Ordóñez-Mena http://orcid.org/0000-0002-8965-104X
Gail Hayward http://orcid.org/0000-0003-0852-627X

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Supplementary Table 1 List of individual tests contained in each test grouping

Group name	**Included tests**[1]
Urine	Urine culture
	Urine microscopy
Genital	Genital culture
	Genital microscopy
Surface swab	Surface swab culture
Faecal	Faecal culture
	Faecal microscopy
	Parasite examination
Antenatal urine	Antenatal urine culture
Dermatophyte	Dermatophyte culture
Pus	Pus culture
	Pus microscopy
Respiratory tract	Upper and/or lower respiratory tract culture
	Upper and/or lower respiratory tract microscopy
	Respiratory tract PCR
Hepatitis B	Hepatitis B surface antigen
	Hepatitis B surface antibody
	Hepatitis B core antibody
	Hepatitis B e antigen
	Anti-HBe antibody
	Anti-HBc IgM
HIV	HIV antigen/antibody/viral load
T. pallidum (syphilis)	Syphilis total antibody screen
Chlamydia	*Chlamydia* test/PCR
Rubella	Rubella screen antibody test
H. pylori (blood antibody test)	*H. pylori* antibody test
Hepatitis C	HCV antibody
	HCV antigen
	HCV viral load
	HCVc test
	Hepatitis C PCR
Cryptosporidium/Giardia	*Cryptosporidium* ELISA
	Cryptosporidium PCR
	Cryptosporidium/Giardia direct antigen test
	Giardia PCR
C. difficile	*C. difficile* GDH/toxin ELISA
	C. difficile assay
Gastrointestinal bacterial panel	Faeces molecular assay (PCR)
Epstein-Barr Virus	Epstein-Barr nuclear antigen IgG
	Epstein-Barr viral capsid antigen IgG
	Epstein-Barr viral capsid antigen IgM

[1] Within each test group, individuals had at least one, but not necessarily all, of the tests listed.

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Supplementary Table 2 Age breakdown of included patients at the time of first test request during the study period

Age group (years)	Number (%) in cohort	% in mid-2018 population estimate for Oxfordshire*
< 14	50,325 (13%)	18%
14–17	10,509 (3%)	3%
18–49	192,034 (49%)	42%
50–64	61,167 (16%)	19%
65–84	63,086 (16%)	16%
≥ 85	16,784 (4%)	3%

* Taken from:
https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/populationestimatesforukenglandandwalesscotlandandnorthernireland

(accessed 19/7/20)

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Supplementary Table 3 Frequency of microbiology tests by age category

Test group	0-13 years				14-17 years				18-49 years				50-65 years				65-84 years				85+ years			
	n	%[1]	N	%[2]	n	%[1]	N	%[2]	n	%[1]	N	%[2]	n	%[1]	N	%[2]	n	%[1]	N	%[2]	n	%[1]	N	%[2]
All tests	111964	100	50325	100	24920	100	12579	100	921136	100	197311	100	185156	100	71076	100	262374	100	72377	100	91202	100	23276	100
Culture +/- Microscopy																								
Urine	62125	55.5	32986	65.6	11230	45.1	7053	56.1	229701	24.9	104712	53.1	105639	57.1	44584	62.7	191476	73.0	56645	78.3	73441	80.5	20244	87.0
Genital	2,369	2.12	1,988	3.95	2314	9.29	1834	14.6	85801	9.31	53348	27.0	12010	6.49	8874	12.5	5501	2.10	4173	5.77	866	0.95	693	2.98
Surface swab	13638	12.2	11203	22.3	1737	6.97	1528	12.2	20523	2.23	16677	8.45	9471	5.12	6849	9.64	16253	6.19	9583	13.2	6666	7.31	3958	17.0
Faecal	13904	12.4	11670	23.2	1243	4.99	1094	8.70	24658	2.68	20486	10.4	11576	6.25	9359	13.2	12931	4.93	10119	14.0	3928	4.31	3129	13.4
Antenatal urine	-	-	-	-	427	1.71	317	2.52	56909	6.18	37671	19.1	-	-	-	-	-	-	-	-	-	-	-	-
Dermatophyte	1286	1.15	1166	2.32	576	2.31	535	4.25	10667	1.16	9398	4.76	6216	3.36	5507	7.75	4961	1.89	4353	6.01	387	0.42	363	1.56
Pus	131	0.12	127	0.25	71	0.28	64	0.51	1834	0.20	1646	0.83	1047	0.57	935	1.32	1389	0.53	1217	1.68	461	0.51	381	1.64
Respiratory tract	73	0.07	49	0.10	37	0.15	26	0.21	416	0.05	267	0.14	674	0.36	387	0.54	1819	0.69	870	1.20	192	0.21	139	0.60
Tests targeting specific pathogens																								
Hepatitis B	392	0.35	365	0.73	1083	4.35	1021	8.12	104880	11.4	70939	36.0	6679	3.61	5894	8.29	3039	1.16	2829	3.91	293	0.32	277	1.19
HIV	152	0.14	143	0.28	886	3.56	829	6.59	95673	10.4	64537	32.7	2005	1.08	1752	2.46	661	0.25	611	0.84	59	0.06	57	0.24
T. pallidum (syphilis)	38	0.03	37	0.07	720	2.89	679	5.40	81974	8.90	55806	28.3	599	0.32	567	0.80	964	0.37	915	1.26	391	0.43	376	1.62
Chlamydia	594	0.53	571	1.13	1450	5.82	1280	10.2	69610	7.56	50182	25.4	4566	2.47	4041	5.69	478	0.18	457	0.63	13	0.01	12	0.05
Rubella	29	0.03	28	0.06	710	2.85	675	5.37	75546	8.20	51020	25.9	244	0.13	233	0.33	24	0.01	23	0.03	3	0.00	3	0.01
H. pylori	487	0.43	480	0.95	914	3.67	884	7.03	27073	2.94	24408	12.4	13332	7.20	12032	16.9	8644	3.29	7806	10.8	687	0.75	642	2.76
Hepatitis C	259	0.23	234	0.46	326	1.31	309	2.46	21553	2.34	17348	8.79	5709	3.08	4954	6.97	2795	1.07	2596	3.59	268	0.29	254	1.09
Cryptosporidium/Giardia	13880	12.4	11650	23.2	209	0.84	190	1.51	5062	0.55	4369	2.21	1805	0.97	1588	2.23	1291	0.49	1157	1.60	175	0.19	165	0.71
C. difficile	242	0.22	227	0.45	64	0.26	53	0.42	1281	0.14	1126	0.57	1008	0.54	898	1.26	7629	2.91	6087	8.41	2751	3.02	2195	9.43
Gastrointestinal bacterial panel¶	1948	1.74	1763	3.50	201	0.81	180	1.43	3352	0.36	3132	1.59	1796	0.97	1656	2.33	2149	0.82	1959	2.71	569	0.62	523	2.25
Epstein-Barr Virus	411	0.37	401	0.80	722	2.90	682	5.42	4623	0.50	4436	2.25	732	0.40	709	1.00	343	0.13	331	0.46	46	0.05	44	0.19

Abbreviations: n: number of tests; **%[1]**: percentage of the total number of tests in the same age category; **N:** number of patients; **%[2]:** percentage of the total number of patients in the same age category.

¶ An enteric pathogen panel that tests for *Shigella* spp., *Salmonella* spp., *Campylobacter* spp. and shiga toxin genes (for the detection of shigatoxigenic *E. coli* such as O157)

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Supplementary Table 4 Frequency of positive test results in men and women

Test group	Male				Female			
	N tests	**Positive**	**Mixed growth**	**Equivocal**	**N tests**	**Positive**	**Mixed growth**	**Equivocal**
Culture +/- Microscopy								
Urine	171,656	20%	21%	2.7%	501,956	29%	27%	3.2%
Genital	648	24%	-	-	108,213	28%	-	-
Surface swab	28,966	43%	-	-	39,322	40%	-	-
Faecal	30,594	12%	-	-	37,646	8.2%	-	-
Antenatal urine	-	-	-	-	57,415	6.6%	25%	1.8%
Dermatophyte	11,278	32%	-	-	12,815	22%	-	-
Pus	2,566	34%	3.0%	-	2,367	37%	3.5%	-
Respiratory tract	1,337	95%	-	-	1,874	93%	-	-
Tests targeting specific organisms		**Positive**				**Positive**		
Hepatitis B	17,952	Surface antigen: 2.9% (435/15259)			98,414	Surface antigen: 0.6% (470/79811) antenatal, 3.5% (521/15100) non-antenatal		
HIV	9,418	1.6%			90,018	0.46%		
Syphilis	1,865	0.75%			82,821	0.04%		
Chlamydia	4,655	5.2%			72,056	2.2%		
Rubella	353	85%			76,203	97%		
H. pylori	21,463	22%			29,674	19%		
Hepatitis C	16,428	Antibody: 6.9% (1075/15527) RNA 56% (587/1039)			14,482	Antibody: 4.0% (558/14034) RNA 40% (192/480)		
Cryptosporidium/Giardia	11,571	2.4%			10,851	2.6%		
C. difficile	5,033	4.6%			7,942	6.4%		
Gastrointestinal bacterial panel[¶]	4,486	19%			5,529	12%		
Epstein-Barr Virus	2,743	EBNA IgG: 68% (1805/2637) VCA IgG: 43% (401/922) VCA IgM: 27% (242/909)			4,134	EBNA IgG: 72% (2844/3955) VCA IgG: 51% (632/1250) VCA IgM: 27% (326/1227)		

[¶] An enteric pathogen panel that tests for *Shigella* spp., *Salmonella* spp., *Campylobacter* spp. and shiga toxin genes (for the detection of shigatoxigenic *E. coli* such as O157)

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Supplementary Table 5 Frequency of positive test results by age category *

Test group	0-13		14-17		18-49		50-64		65-84		85+	
	N tests	Positive	N tests	Positive	N tests	Positive	N tests	Positive	N tests	Positive	N tests	Positive
Cultures & Microscopies												
Urine	62,125	19%	11,230	26%	229,701	21%	105,639	28%	191,476	33%	73,441	33%
Genital	2,369	40%	2,314	34%	85,801	29%	12,010	20%	5,501	19%	866	20%
Surface swab	13,638	44%	1,737	33%	20,523	36%	9,471	40%	16,253	43%	6,666	48%
Faecal	13,904	6.0%	1,243	13%	24,658	12%	11,576	13%	12,931	8.1%	3,928	2.0%
Antenatal urine	-	-	427	9.4%	56,909	6.5%	48	8.3%	27	33%	-	-
Dermatophyte	1,286	23%	576	25%	10,667	29%	6,216	26%	4,961	23%	387	27%
Pus	131	47%	71	54%	1,834	40%	1,047	32%	1,389	29%	461	35%
Respiratory tract	73	82%	37	97%	416	92%	674	93%	1,819	95%	192	92%
Tests targeting specific organisms†												
Hepatitis B	392	0.32%	1,083	0.90%; 0.84%	104,880	0.59%; 3.9%	6,679	1.7%	3,039	0.62%	293	-
HIV	152	-	886	0.34%	95,673	0.51%	2,005	2.9%	661	0.91%	59	-
Syphilis	38	-	720	-	81,974	0.05%	599	0.50%	964	0.62%	391	-
Chlamydia	594	2.9%	1,450	4.6%	69,610	2.4%	4,566	1.1%	478	0.42%	13	-
Rubella	29	79%	710	85%	75,546	97%	244	86%	24	75%	-	-
H. pylori	487	6.2%	914	10%	27,073	20%	13,332	19%	8,644	23%	687	28%
Hepatitis C	259	4.9%	326	0.6%	21,553	5.7%; 51%	5,709	7.0%; 55%	2,795	2.3%; 44%	268	0.8%
Cryptosporidium/Giardia	13,880	2.3%	209	1.0%	5,062	3.2%	1,805	1.9%	1,291	2.3%	175	0.57%
C. difficile	242	5.4%	64	7.8%	1,281	6.5%	1,008	5.2%	7,629	4.7%	2,751	8.3%
Gastrointestinal bacterial panel[¶]	1,948	9.3%	201	22%	3,352	19%	1,796	20%	2,149	14%	569	5.8%
Epstein-Barr Virus	411	37%; 15%; 11%	722	40%; 38%; 28%	4,623	75%; 53%; 31%	732	85%; 75%; 17%	343	83%; 76%; 22%	46	93%

* The percentage of cultures with mixed growth or equivocal results was comparable across age groups and therefore not shown in this table. Frequencies below 10 are not shown.

† Percentages of positive results are shown for the Hepatitis B, Hepatitis C and Epstein-Barr Virus test groups as follows (as in Table 1). Hepatitis B: surface antigen antenatal (in 14-17 and 18-49 age groups only); non-antenatal. Hepatitis C: antibody; RNA (in 18-49. 50-64 and 65-84 age groups only, as counts in other age groups were small). Epstein-Barr Virus: EBNA IgG; VCA IgG; VCA IgM (VCA percentages excluded from 85+ age group as counts were small).

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[¶] An enteric pathogen panel that tests for *Shigella* spp., *Salmonella* spp., *Campylobacter* spp. and shiga toxin genes (for the detection of shigatoxigenic *E. coli* such as O157)

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Supplementary Table 6 Frequency and percentage of the five most common organisms detected for each test group, by age category

0-13 years			14-17 years			18-49 years			50-64 years			65-84 years			85+ years		
Test group Organism	**N***	**%**	**Test group** Organism	**N***	**%**	**Test group** Organism	**N***	**%**	**Test group** Organism	**N***	**%**	**Test group** Organism	**N***	**%**	**Test group** Organism	**N***	**%**
Urine	**11704**	**100**	**Urine**	**2962**	**100**	**Urine**	**48115**	**100**	**Urine**	**29795**	**100**	**Urine**	**63555**	**100**	**Urine**	**23916**	**100**
E. coli	8996	77	*E. coli*	2146	73	*E. coli*	36298	75	*E. coli*	23137	78	*E. coli*	45389	71	*E. coli*	16261	68
Enterococcus spp.	1233	11	*Staphylococcus* spp.	422	14	*Enterococcus* spp.	3836	8.0	*Enterococcus* spp.	1858	6.2	*Enterococcus* spp.	4546	7.2	*Proteus* spp.	1516	6.3
Proteus spp.	474	4.1	*Enterococcus* spp.	153	5.2	*Staphylococcus* spp.	2896	6.0	*Streptococcus* spp.	1086	3.6	*Klebsiella* spp.	3472	5.5	*Enterococcus* spp..	1467	6.1
Staphylococcus spp.	411	3.5	*Proteus* spp.	74	2.5	*Streptococcus* spp.	1639	3.4	*Klebsiella* spp.	1014	3.4	*Proteus* spp.	2894	4.6	*Pseudomonas* spp.	1376	5.8
Pseudomonas spp.	158	1.4	*Streptococcus* spp.	61	2.1	*Klebsiella* spp.	1005	2.1	*Proteus* spp.	773	2.6	*Pseudomonas* spp.	2233	3.5	*Klebsiella* spp.	1374	5.8
Other	432	3.7	Other	106	3.6	Other	2444	5.1	Other	1930	6.5	Other	5025	7.9	Other	1922	8.0
Genital	**947**	**100**	**Genital**	**782**	**100**	**Genital**	**24972**	**100**	**Genital**	**2370**	**100**	**Genital**	**1027**	**100**	**Genital**	**172**	**100**
MSA	443	47	*Candida* spp.	619	79	*Candida* spp.	18423	74	*Candida* spp.	1642	69	*Candida* spp.	810	79	*Candida* spp.	142	83
Streptococcus spp.	373	39	MSA	118	15	MSA	4261	17	*Streptococcus* spp.	428	18	MSA	110	11	MSA	16	9.3
Candida spp.	131	14	*Streptococcus* spp.	89	11	*Streptococcus* spp.	3415	14	MSA	368	16	*Streptococcus* spp.	108	11	*Streptococcus* spp.	8	4.7
Staphylococcus spp.	96	10	*Staphylococcus* spp.	21	2.7	*Staphylococcus* spp.	487	2.0	*Staphylococcus* spp.	43	1.8	*E. coli*	26	2.5	*E. coli*	4	2.3
E. coli	44	4.7	*E. coli*	3	0.4	*E. coli*	278	1.1	*E. coli*	38	1.6	*Staphylococcus* spp.	25	2.4	*Staphylococcus* spp.	4	2.3
Other	6	0.6	Other	2	0.3	Other	24	0.1	Other	5	0.2	Other	4	0.4	Other	4	2.3
Surface Swab	**6030**	**100**	**Surface Swab**	**577**	**100**	**Surface Swab**	**7481**	**100**	**Surface Swab**	**3758**	**100**	**Surface Swab**	**6998**	**100**	**Surface Swab**	**3185**	**100**
Streptococcus spp.	2815	47	*Staphylococcus* spp.	380	66	*Staphylococcus* spp.	4234	57	*Staphylococcus* spp.	2430	65	*Staphylococcus* spp.	5022	72	*Staphylococcus* spp.	2508	79
Staphylococcus spp.	2224	37	*Streptococcus* spp.	171	30	*Streptococcus* spp.	2427	32	*Streptococcus* spp.	1043	28	*Streptococcus* spp.	1484	21	*Streptococcus* spp.	555	17
Haemophilus spp.	964	16	*Candida* spp.	67	12	*Candida* spp.	1189	16	*Candida* spp.	593	16	*Candida* spp.	809	12	*Candida* spp.	211	6.6
Candida spp.	358	5.9	MSA	12	2.1	MSA	370	5	MSA	115	3.1	MSA	295	4.2	MSA	149	4.7
Moraxella spp.	217	3.6	*Aspergillus* spp.	5	0.9	*Pseudomonas* spp.	58	0.8	*Pseudomonas* spp.	41	1.1	*Pseudomonas* spp.	93	1.3	*Pseudomonas* spp.	71	2.2
Other	295	4.9	Other	5	0.9	Other	74	1	Other	62	1.7	Other	66	0.9	Other	23	0.7
Faecal	**831**	**100**	**Faecal**	**163**	**100**	**Faecal**	**3025**	**100**	**Faecal**	**1505**	**100**	**Faecal**	**1046**	**100**	**Faecal**	**79**	**100**
Campylobacter spp.	586	71	*Campylobacter* spp.	140	86	*Campylobacter* spp.	2546	84	*Campylobacter* spp.	1331	88	*Campylobacter* spp.	958	92	*Campylobacter* spp.	70	89
Salmonella spp.	154	19	*Salmonella* spp.	20	12	*Salmonella* spp.	244	8.1	*Salmonella* spp.	125	8.3	*Salmonella* spp.	57	5.5	*Salmonella* spp.	8	10
Giardia lamblia	48	5.8	*Shigella* spp.	3	1.8	*Giardia lamblia*	170	5.6	*Giardia lamblia*	39	2.6	*Giardia lamblia*	28	2.7	*Giardia lamblia*	1	1.3
E. coli	42	5.1	*Giardia lamblia*	2	1.2	*Shigella* spp.	58	1.9	*Shigella* spp.	12	0.8	*E. coli*	6	0.6	*Shigella* spp.	1	1.3
Shigella spp.	7	0.8	*E. coli*	1	0.6	*E. coli*	26	0.9	*E. coli*	7	0.5	*Shigella* spp.	2	0.2	-	-	-
Other	7	0.8	Other	1	0.6	Other	4	0.1	Other	7	0.5	Other	2	0.2	Other	1	1.3
Antenatal urine	**-**	**-**	**Antenatal urine**	**40**	**100**	**Antenatal urine**	**3718**	**100**	**Antenatal urine**	**-**	**-**	**Antenatal urine**	**-**	**-**	**Antenatal urine**	**-**	**-**
-	-	-	*E. coli*	27	68	*E. coli*	1759	47	-	-	-	-	-	-	-	-	-
-	-	-	*Enterococcus* spp.	5	13	*Enterococcus* spp.	1244	34	-	-	-	-	-	-	-	-	-
-	-	-	*Streptococcus* spp.	4	10	*Streptococcus* spp.	320	8.6	-	-	-	-	-	-	-	-	-
-	-	-	*Staphylococcus* spp.	2	5.0	*Staphylococcus* spp.	190	5.1	-	-	-	-	-	-	-	-	-
-	-	-	Candida spp.	2	5.0	Candida spp.	97	2.6	-	-	-	-	-	-	-	-	-

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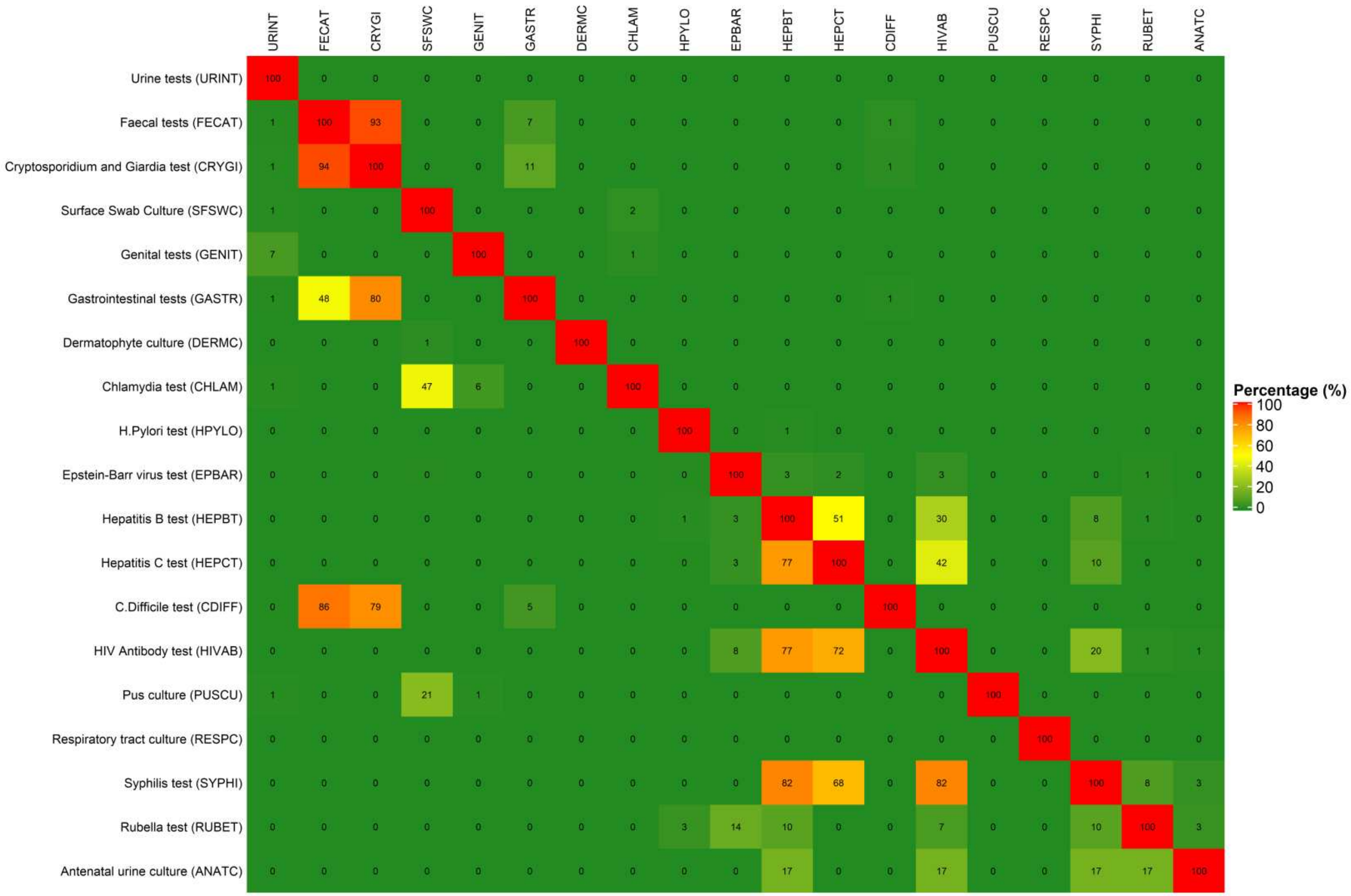
-	-	-	Other	2	5.0	Other	108	2.9	-	-	-	-	-	-	-	-	-
Dermatophyte	**300**	**100**	**Dermatophyte**	**144**	**100**	**Dermatophyte**	**3102**	**100**	**Dermatophyte**	**1637**	**100**	**Dermatophyte**	**1165**	**100**	**Dermatophyte**	**104**	**100**
Trichophyton spp.	287	96	*Trichophyton* spp.	137	95	*Trichophyton* spp.	2875	93	*Trichophyton* spp.	1448	89	*Trichophyton* spp.	938	81	*Trichophyton* spp.	61	59
Candida spp.	16	5.3	*Candida* spp.	5	3.5	*Candida* spp.	181	5.8	*Candida* spp.	146	8.9	*Candida* spp.	190	16	*Candida* spp.	39	38
-	-	-	*Acremonium* spp.	1	0.7	*Fusarium* spp.	45	1.5	*Fusarium* spp.	26	1.6	*Fusarium* spp.	22	1.9	*Acremonium* spp.	3	2.9
-	-	-	Fungal elements seen	1	0.7	*Acremonium* spp.	20	0.6	*Acremonium* spp.	24	1.5	*Acremonium* spp.	20	1.7	*Scopulariopsis* spp.	1	1.0
-	-	-	*Fusarium* spp.	1	0.7	*Scopulariopsis* spp.	8	0.3	*Scopulariopsis* spp.	19	1.2	*Scopulariopsis* spp.	16	1.4	-	-	-
Other	16	5.3	Other	1	0.7	Other	4	0.1	Other	19	1.2	Other	3	0.3	Other	1	1.0
Pus	**62**	**100**	**Pus**	**38**	**100**	**Pus**	**734**	**100**	**Pus**	**331**	**100**	**Pus**	**397**	**100**	**Pus**	**163**	**100**
Staphylococcus spp.	49	79.0	*Staphylococcus* spp.	30	79	*Staphylococcus* spp.	471	64	*Staphylococcus* spp.	196	59	*Staphylococcus* spp.	230	58	*Staphylococcus* spp.	100	61
Streptococcus spp.	6	9.7	*Streptococcus* spp.	4	11	*Streptococcus* spp.	157	21	*Streptococcus* spp.	58	18	*Pseudomonas* spp.	71	18	*Pseudomonas* spp.	40	25
E. coli	2	3.2	MSA	3	7.9	*E. coli*	51	7.0	*Pseudomonas* spp.	32	9.7	*Streptococcus* spp.	55	14	*Streptococcus* spp.	15	9.2
MSA	2	3.2	*Pseudomonas* spp.	3	7.9	MSA	41	5.6	MSA	24	7.3	*E. coli*	33	8.3	*E. coli*	13	8.0
Pseudomonas spp.	2	3.2	*E. coli*	2	5.3	*Pseudomonas* spp.	38	5.2	*E. coli*	22	6.7	MSA	23	5.8	*Enterococcus* spp.	8	4.9
Other	4	6.5	Other	3	7.9	Other	82	11	Other	42	13	Other	63	16	Other	24	15
Respiratory tract	**60**	**100**	**Respiratory tract**	**36**	**100**	**Respiratory tract**	**381**	**100**	**Respiratory tract**	**627**	**100**	**Respiratory tract**	**1724**	**100**	**Respiratory tract**	**176**	**100**
Haemophilus spp.	29	48	*Staphylococcus* spp.	18	50.0	*Haemophilus* spp.	201	53	*Haemophilus* spp.	288	46	*Haemophilus* spp.	624	36	*Pseudomonas* spp.	60	34
Staphylococcus spp.	15	25.0	*Pseudomonas* spp.	6	17	*Staphylococcus* spp.	59	16	*Pseudomonas* spp.	176	28	*Pseudomonas* spp.	584	34	*Haemophilus* spp.	56	32
Streptococcus spp.	12	20.0	*Haemophilus* spp.	5	14	*Streptococcus* spp.	54	14	*Streptococcus* spp.	67	11	*Streptococcus* spp.	166	9.6	*Moraxella* spp.	20	11
Pseudomonas spp.	10	17	*Streptococcus* spp.	4	11	*Pseudomonas* spp.	44	12	*Moraxella* spp.	61	9.7	*Moraxella* spp.	155	9.0	*Staphylococcus* spp.	17	9.7
Moraxella spp.	8	13	*E. coli*	2	5.6	*Moraxella* spp.	38	10	*Staphylococcus* spp.	59	9.4	*Staphylococcus* spp.	138	8.00	*E. coli*	16	9.1
Other	3	5.00	Other	7	19	Other	33	8.7	Other	51	8.1	Other	228	13	Other	30	17

Abbreviations: N: number of positives; **%**: percentage of all positive tests in that age category for that particular type of culture in which the pathogen in the row was detected; **MSA:** Metronidazole-sensitive anaerobe.

* The number of positives for all pathogens may not add to the total positive due to some cultures being positive for more than one pathogen.

Supplementary Figure 1 Heat-map showing the percentage of all tests in the row that were also accompanied by the test in the column in children aged 0 to 13 years.



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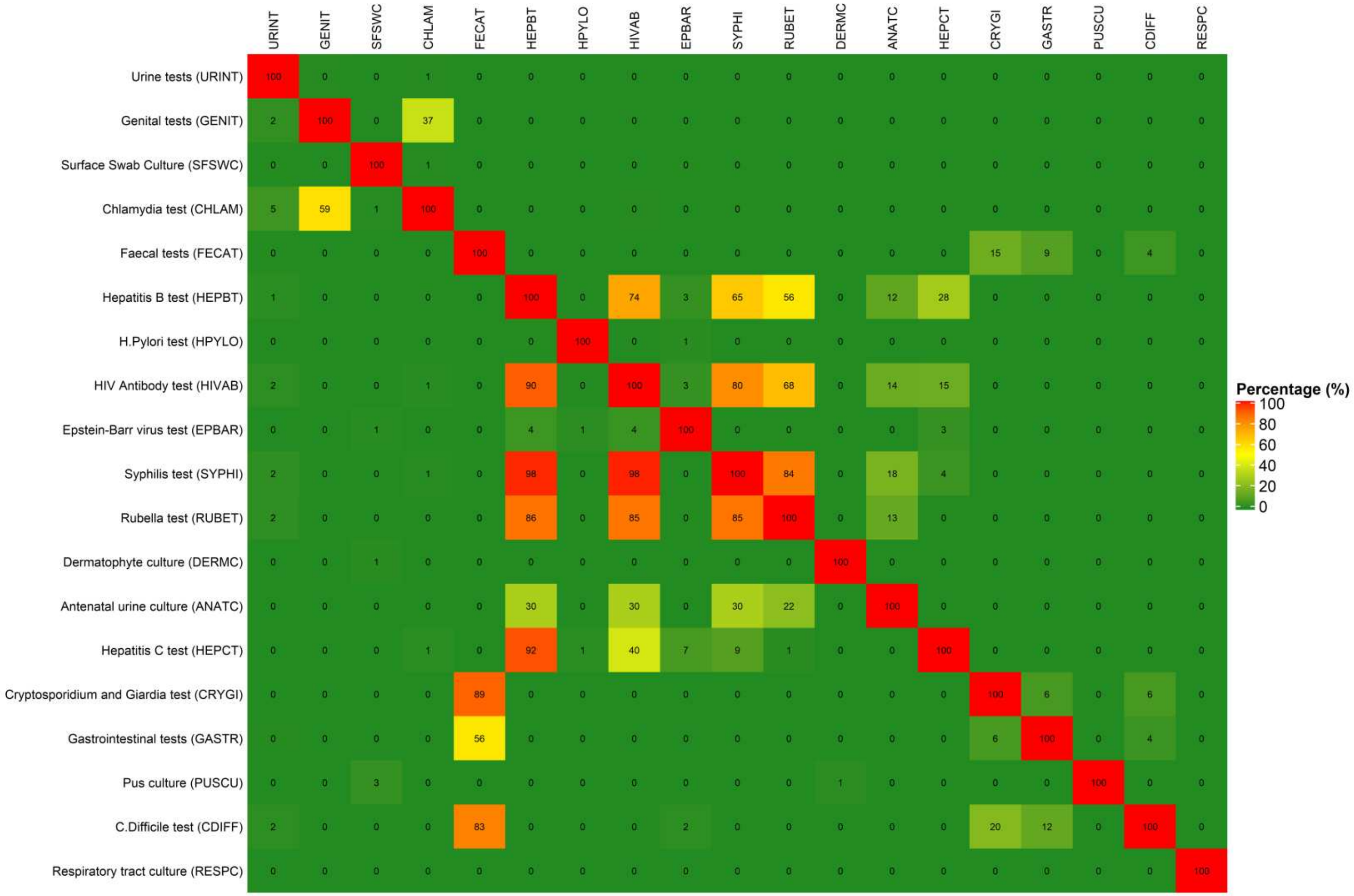
Supplementary Figure 2 Heat-map showing the percentage of all tests in the row that were also accompanied by the test in the column in children aged 14 to 17 years.



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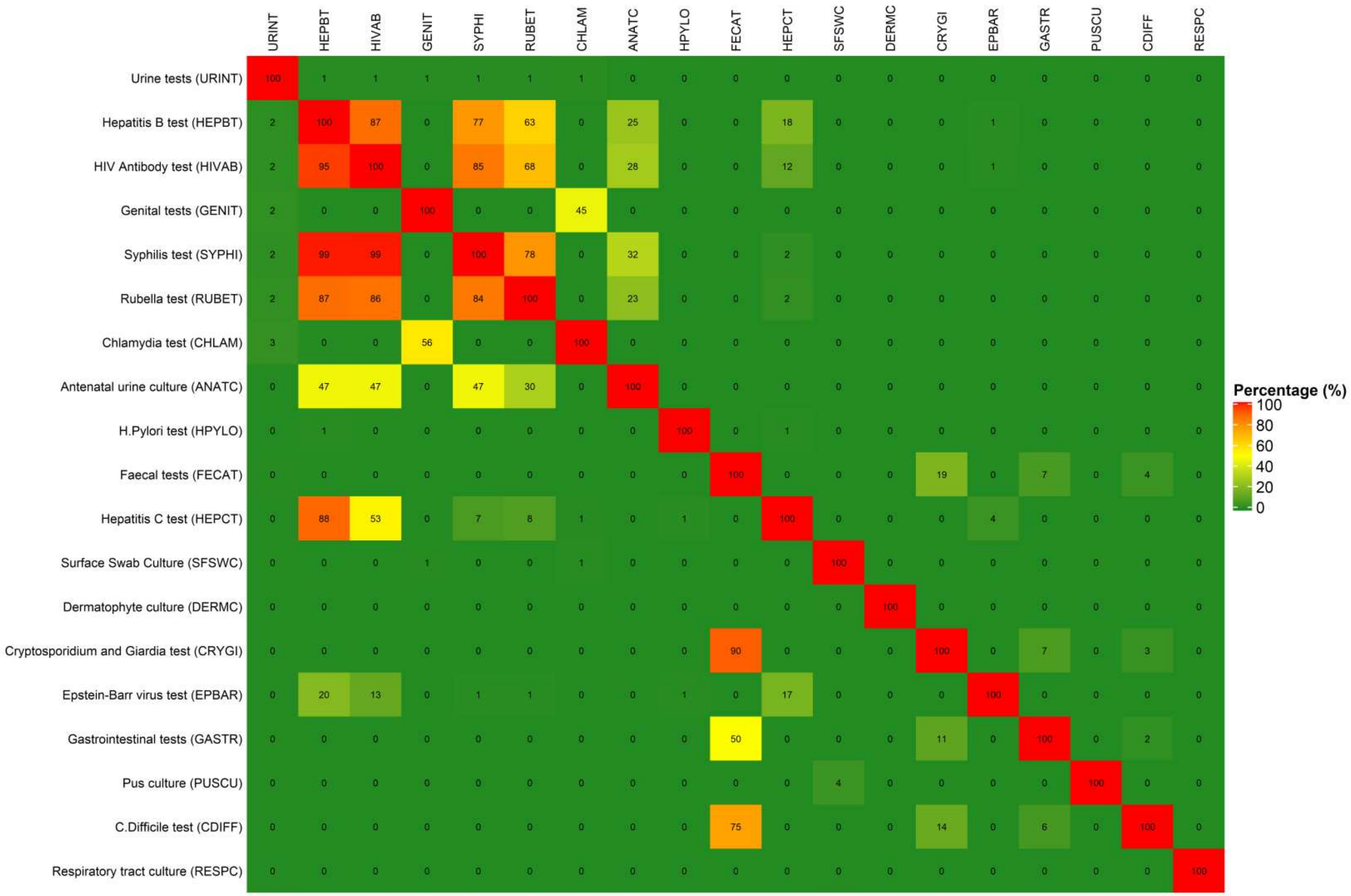
Supplementary Figure 3 Heat-map showing the percentage of all tests in the row that were also accompanied by the test in the column in adults aged 18 to 49 years.



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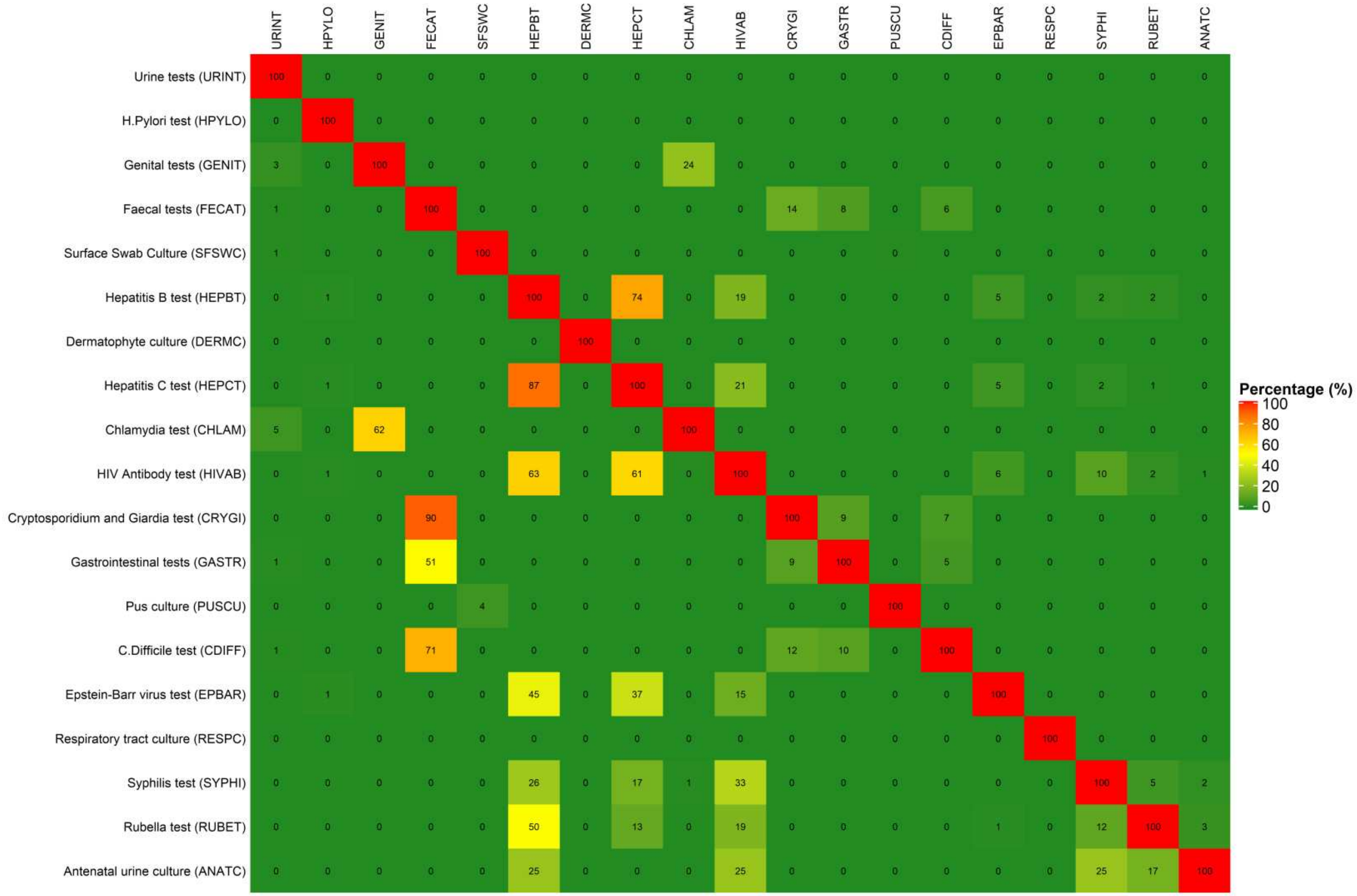
Supplementary Figure 4 Heat-map showing the percentage of all tests in the row that were also accompanied by the test in the column in adults aged 50 to 64 years.



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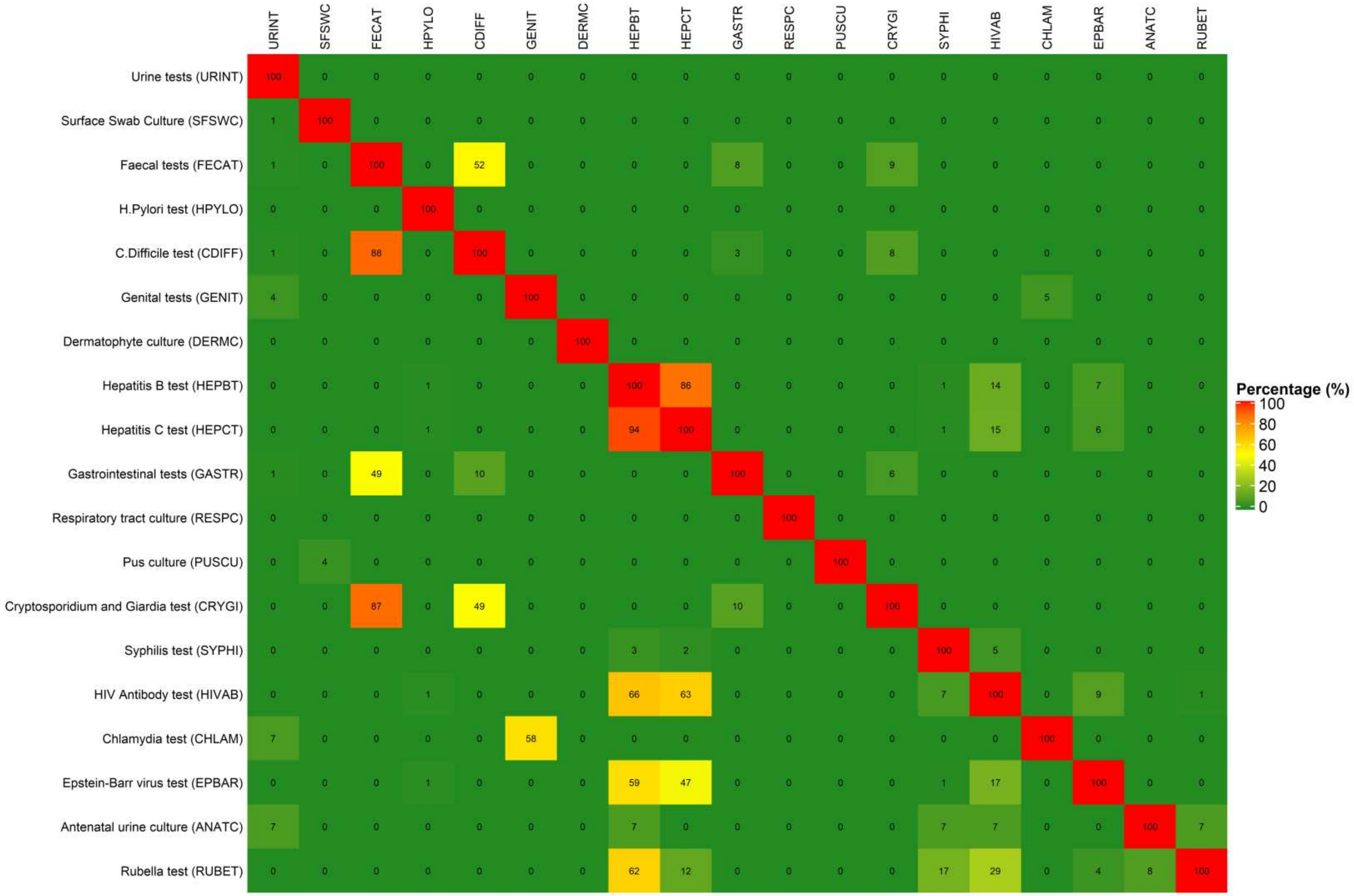
Supplementary Figure 5 Heat-map showing the percentage of all tests in the row that were also accompanied by the test in the column in adults aged 65 to 84 years.



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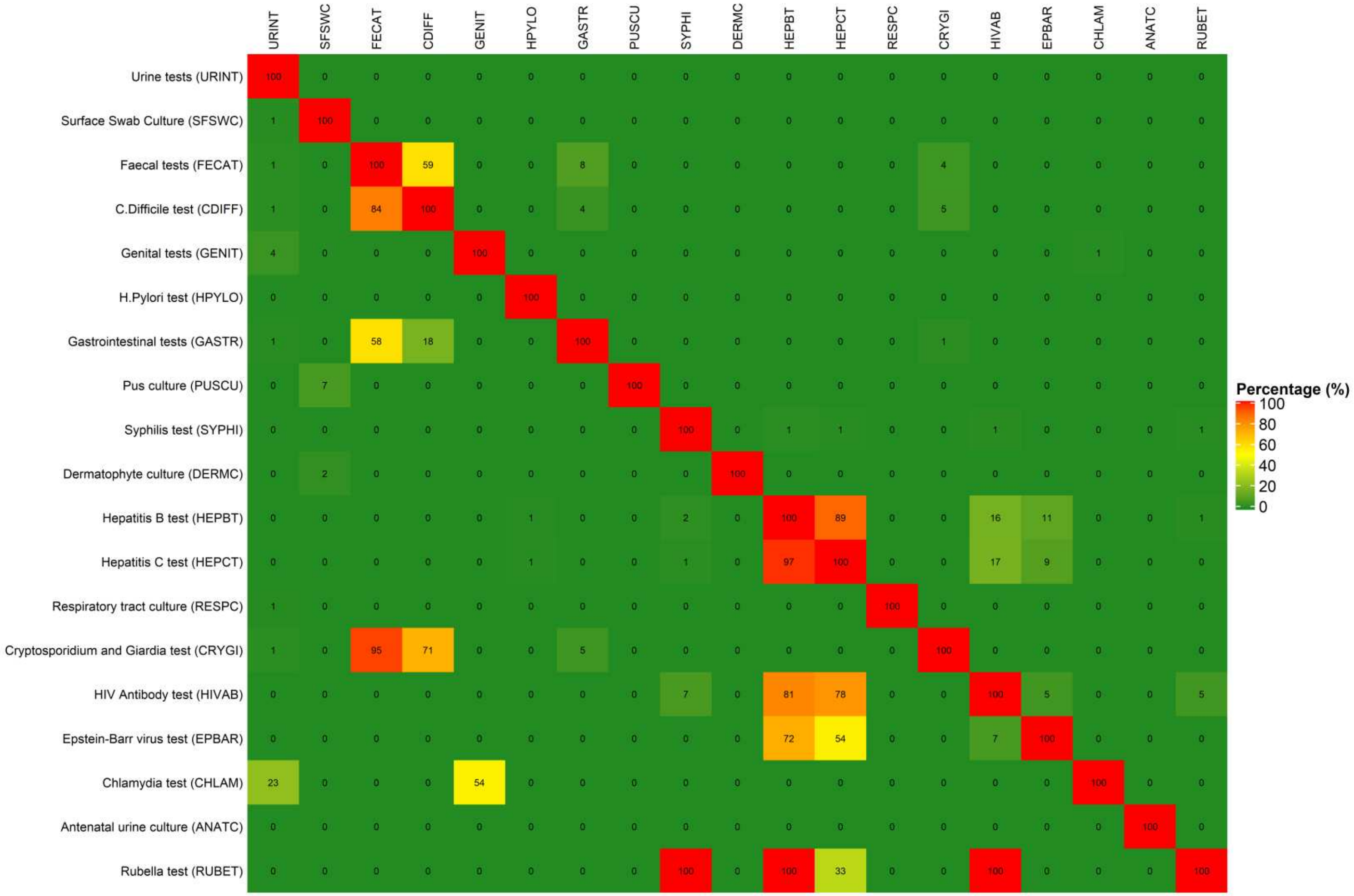
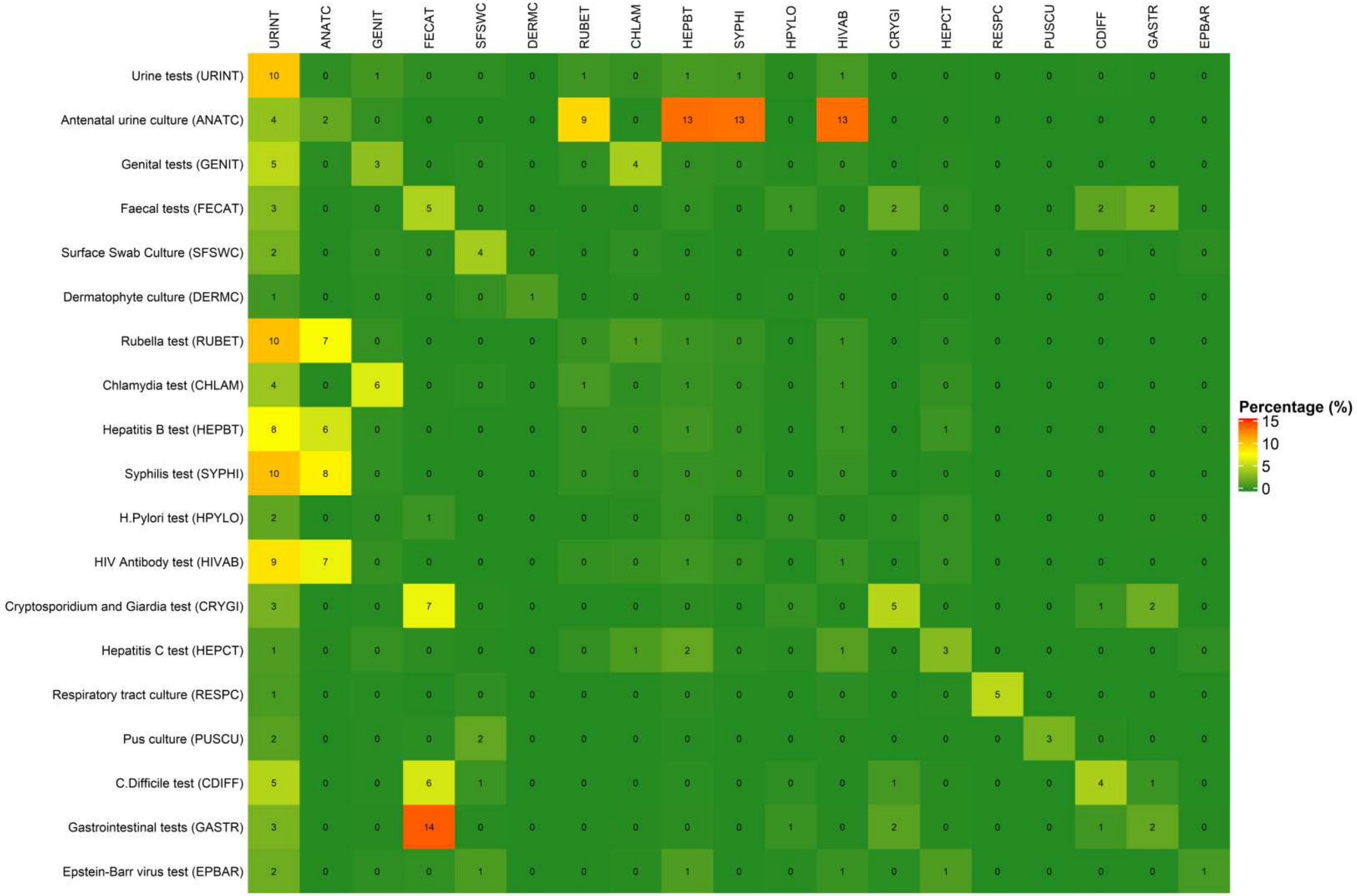
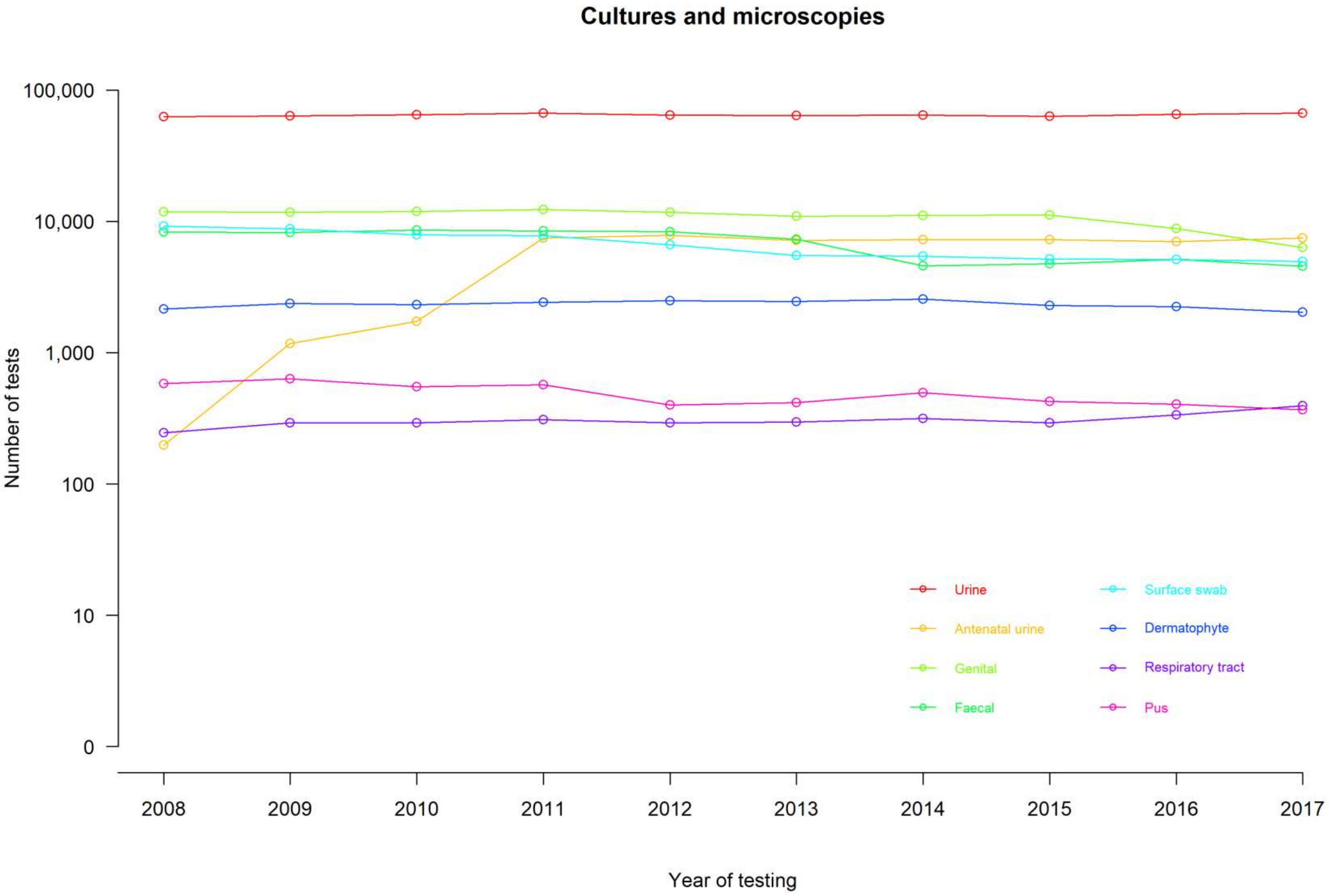
Supplementary Figure 6 Heat-map showing the percentage of all tests in the row that were also accompanied by the test in the column in adults aged 85 years and over.



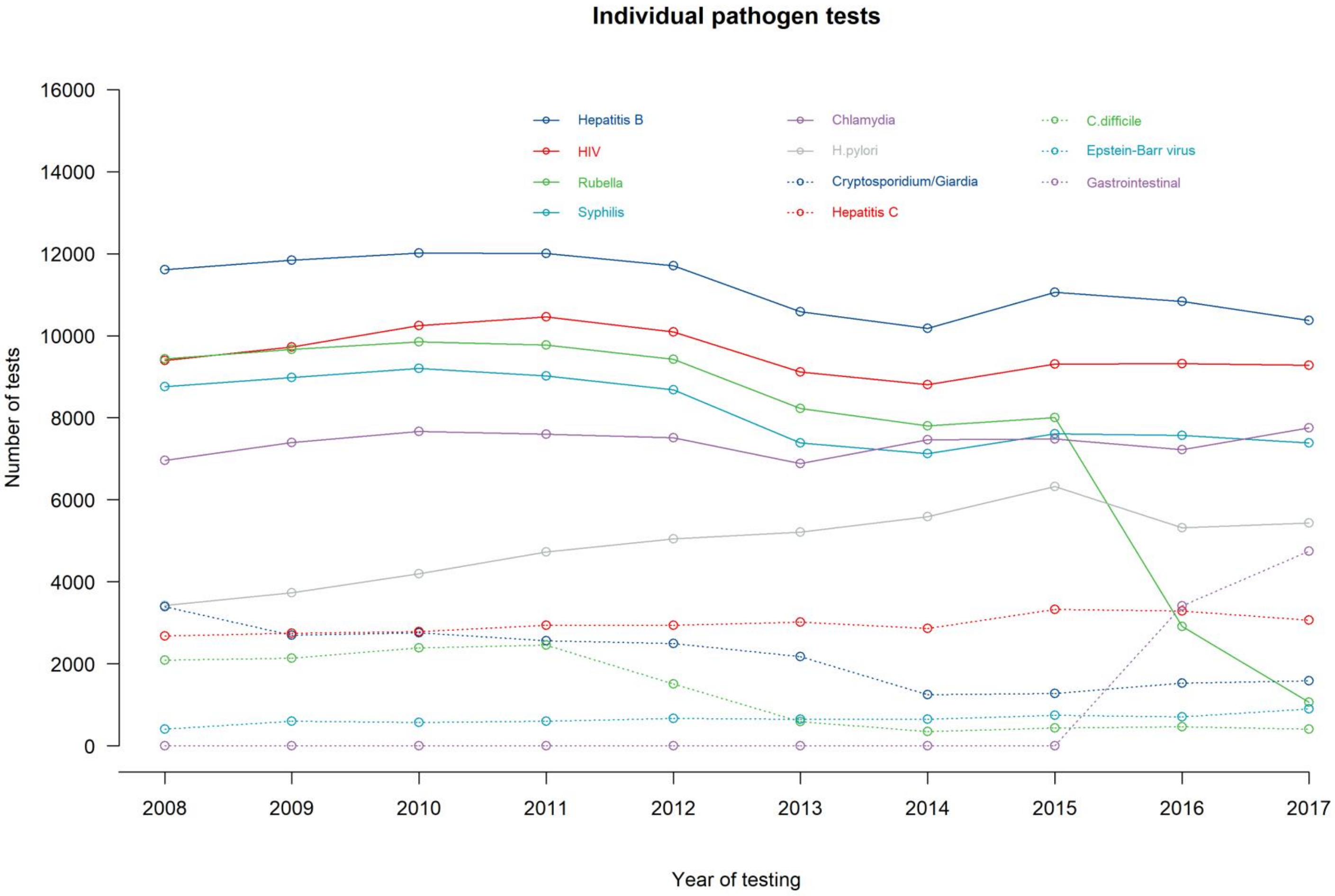
Supplementary Figure 7 Heat-map showing the percentage of all tests in the row that were followed by the test in the column within 14 days.



Supplementary Figure 8 Plot of test type frequency over time.



Supplementary Figure 9 Plot of frequencies of individual pathogen and gastrointestinal tests over time.



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