Costs and health consequences of chlamydia management strategies among pregnant women in sub-Saharan Africa

M Romoren, F Hussein, T W Steen, M Velauthapillai, J Sundby, P Hjortdahl, I S Kristiansen

Sex Transm Infect 2007;**83**:558–566. doi: 10.1136/sti.2007.026930

The technical report and web references can be viewed in the supplemental section online at <http://sti.bmj.com/supplemental>

See end of article for authors' affiliations

Correspondence to: M Romoren, Faculty of Medicine, University of Oslo, Box 1130 Blindern, N-0318 Oslo, Norway; maria.romoren@medisin.uio.no

Accepted 6 October 2007

Objectives: Chlamydia is the most common bacterial sexually transmitted infection worldwide and a major cause of morbidity—particularly among women and neonates. We compared costs and health consequences of using point-of-care (POC) tests with current syndromic management among antenatal care attendees in sub-Saharan Africa. We also compared erythromycin with azithromycin treatment and universal with age-based chlamydia management.

Methods: A decision analytical model was developed to compare diagnostic and treatment strategies, using Botswana as a case. Model input was based upon (1) a study of pregnant women in Botswana, (2) literature reviews and (3) expert opinion. We expressed the study outcome in terms of costs (US\$), cases cured, magnitude of overtreatment and successful partner treatment.

Results: Azithromycin was less costly and more effective than erythromycin. Compared with syndromic management, testing all attendees on their first visit with a 75% sensitive POC test increased the number of cases cured from 1500 to 3500 in a population of 100 000 women, at a cost of US\$38 per additional case cured. This cost was lower in high-prevalence populations or if testing was restricted to teenagers. The specific POC tests provided the advantage of substantial reductions in overtreatment with antibiotics and improved partner management.

Conclusions: Using POC tests to diagnose chlamydia during antenatal care in sub-Saharan Africa entails greater health benefits than syndromic management does—and at acceptable costs—especially when restricted to younger women. Changes in diagnostic strategy and treatment regimens may improve people's health and even reduce healthcare budgets.

Chlamydia trachomatis infection is the most common bacterial sexually transmitted infection (STI) worldwide, with highest prevalences in sub-Saharan Africa.¹ In women, chlamydia can progress to pelvic inflammatory disease, and subsequently cause ectopic pregnancy and infertility. The risk of intrauterine growth retardation, preterm birth, perinatal conjunctivitis and pneumonia, and postpartum upper genital tract infections makes treatment in pregnancy desirable.^{2–3} Because STIs can enhance HIV transmission, UNAIDS and WHO recommend the improvement of STI control.^{4–5}

In developing countries, the diagnosis of chlamydia has been limited to the syndromic approach, a strategy that is neither sensitive nor specific.^{3–8} The majority of infected women are asymptomatic and will not be diagnosed and treated, and high levels of overtreatment increase drug costs and the risk of drug resistance.⁸ Simple, affordable point-of-care (POC) tests are needed to improve chlamydia management in the developing world.⁹ Tests with moderate sensitivity and high specificity are commercially available, and more sensitive tests are under development.^{7–9–10}

The aim of this economic evaluation was to estimate, from the healthcare perspective, incremental costs and health consequences in sub-Saharan Africa of testing all antenatal care attendees with a POC test on their first visit. Treating the women with azithromycin was compared with erythromycin treatment; and, as chlamydia is strongly correlated with youth,^{11–12} we also compared the management of teenagers or women under 30 years of age to universal management. Our case was Botswana, a country with 7.5% prevalence of chlamydia and 32% HIV prevalence among antenatal care attendees.^{13–14} Screening for syphilis and HIV in pregnancy is routine, and all clinics and health

posts perform POC tests for HIV, suggesting that it would be feasible to use POC tests for chlamydia in this setting.

METHODS

Decision analytical model

We used TreeAge Pro software to develop a decision analytical model, comparing the use of POC tests with syndromic management in a hypothetical cohort of 100 000 antenatal care attendees (fig 1). The structure of the decision tree branches is identical for the two diagnostic strategies, but the probabilities of events differ. We assigned costs to each branch, using the number of cured infections as the measure of benefit. The model captures programme costs, the number of cured infections and reinfections among attendees and their partners, and the number and cost of patients unnecessarily treated with antibiotics.

Information to feed the decision tree was based on literature reviews and Medline searches for data on all probabilities and costs, a cross-sectional study among 703 antenatal care attendees in Gaborone, the capital of Botswana,^{12–14} and advice from an expert panel. The model probabilities are presented in table 1. The model is described in full in a technical report, available online.¹⁵

Probabilities

The general and age-specific prevalences of chlamydia were based on the Gaborone study.^{14–15} These prevalences correspond with those among pregnant women in other sub-Saharan countries, but prevalences from 3% to 31% have been found.^{3–8} Prevalences may differ in other settings or change over time.

Abbreviations: POC, point-of-care; SA, syndromic approach

Figure 1 Key structure of the decision tree and its branches.

Table 1 Model probabilities

Parameter	Probability		Source
	Base-case value	Lower and upper bounds	
Probabilities common to both strategies			
Chlamydia trachomatis prevalence			
Prevalence among all antenatal care attendees	0.075	0.06 to 0.10	A
Prevalence among attendees < 30 years	0.093	0.07 to 0.12	A
Prevalence among attendees < 20 years	0.158	0.09 to 0.26	A
Chlamydia trachomatis transmission rate	0.80	0.50 to 0.96	Ref w1–w4, B
Infected male with symptomatic infection	0.15	0.10 to 0.20	Ref w10–w12, B
Symptomatic male seeking care independently	0.50	0.30 to 0.70	Ref w12, w13, B
Symptomatic male cured independently	0.50	0.30 to 0.70	Ref w12, w13, B
Variables in the syndromic approach strategy			
Syndromic approach sensitivity	0.49	0.36 to 0.62	A
Syndromic approach specificity	0.65	0.61 to 0.69	A
Prescription of treatment to diagnosed attendee	0.85	0.79 to 0.90	Ref 14, A
Female compliant to erythromycin and drug effectiveness	0.50	0.30 to 0.70	Ref 14, w14, w15, A, B
Female compliant to azithromycin and drug effectiveness	0.95	0.88 to 1.00	Ref w14–w17
Male partner notified and attended clinic	0.09	0.06 to 0.11	Ref w11, w12, w18–w21
Prescription of treatment to attending partner	0.85	0.76 to 1.00	Ref w22, w23, B
Male compliant to doxycycline and drug effectiveness	0.80	0.60 to 1.00	Ref w15, w16, B
Variables in the point-of-care strategy			
Point-of-care test sensitivity	0.75	0.50 to 0.85	Ref 9, 10, 17, w5, w24
Point-of-care test specificity	0.985	0.97 to 1.00	Ref 9, 10, 17, w24
Prescription of treatment to diagnosed attendee	0.93	0.85 to 1.00	Ref 14, 22, 23, A, B
Female compliant to erythromycin and drug effectiveness	0.86	0.50 to 0.95	Ref 14, w14, w15, A, B
Female compliant to azithromycin and drug effectiveness	0.95	0.88 to 1.00	Ref w14–w17
Male partner notified and attends clinic	0.25	0.09 to 0.65	Ref w11, w12, w18–w21, w25, w26, B
Prescription of treatment to attending partner	0.93	0.85 to 1.00	Ref 22, 23, w22, w23, w27, B
Male compliant to doxycycline and drug effectiveness	0.90	0.80 to 1.00	Ref w15, w16, B

A, data from the original study among antenatal care attendees in Botswana; B, expert judgment. Further supporting evidence is presented in the technical report.

and to estimate the effect of prevalence on the results, this range was used in the one-way sensitivity analysis. The chlamydia transmission rate was based on co-infection studies among STI patients and on expert opinion.^{15, w1–w4} For the w-references, please see the additional web reference list.

The sensitivity and specificity of the syndromic approach in the diagnosis of chlamydia in pregnancy were based on the Gaborone study—figures similar to those of other studies from sub-Saharan Africa.^{3 15 16} A pregnant woman diagnosed as having vaginal discharge syndrome may have normal pregnancy-related discharge or symptoms caused by candida, bacterial vaginosis or trichomoniasis—or, less likely, chlamydia or gonorrhoea. This uncertainty, coupled with the fact that the

syndrome requires up to four drug regimens, reduces nurses' adherence to treatment guidelines, patient compliance, and incentives to ensure partner notification.⁸ With syndromic management, these variables were based on expert knowledge of the situation in developing countries, indirect study data and available evidence (table 1).

The sensitivity of available POC tests have shown considerable variability (25–85%).^{w5} A recent evaluation of a widely used test found 50% sensitivity,¹¹ and more sensitive tests are under development.¹⁷ We evaluated 50–85% sensitive tests, and exemplify with 50% and 75% sensitive tests in the text. All POC tests for chlamydia have high specificity.^{9 10} A positive test requires prescription of and compliance with one drug regimen.

Table 2 Model costs (2006 US\$)

Resources used	Base-case value	Lower and upper bounds	Unit	Source
Personnel costs				
Pharmacy technician	4.95	2.48–7.43	\$/h	Ref w6, w7
Lay worker	1.98	0.99–2.97	\$/h	Ref w6, w7
Dispensing (3 min × C _{pharmacy technician})	0.25	0.12–0.37	\$/episode	A
Testing (5 min × C _{lay worker})	0.17	0.08–0.25	\$/episode	A
Unit costs				
Erythromycin	1.49	0.37–6.60	\$/drug regimen	Ref w8, w9
Azithromycin	0.74	0.43–1.65	\$/drug regimen	Ref w9
Doxycycline	0.25	0.11–1.56	\$/drug regimen	Ref w8, w9
POC test	0.85	0.50–4.00	\$/test	Ref 7, 18
Treatment (cost of drug+cost of dispensing)*				
Erythromycin treatment	1.74	0.49–6.97	\$/episode	
Azithromycin treatment	0.98	0.55–2.02	\$/episode	
Doxycycline treatment	0.50	0.23–1.93	\$/episode	
Testing with POC test (cost of test+cost of testing)†	1.02	0.58–4.25	\$/episode	

*Modelled costs for the syndromic management strategy and the POC-test strategy.

†Modelled additional costs for the POC-test strategy.

A, data from the original study among antenatal care attendees in Botswana; C, cost; POC, point-of-care.

Data on the management with POC tests are lacking. The expert panel inflated the values used for the probabilities in the syndromic strategy, assuming that the additional confidence in the POC test result would improve management (table 1). The possibility that this is not the case is covered by using large uncertainty bounds, including in the lower bound a value that represents syndromic management. The upper bound represents much better performance, as found in developed countries where specific chlamydia tests are in use.

Costs

The costs were modelled from the providers' perspective and presented in 2006 US\$ (table 2). For syndromic management, we included direct drug costs and the cost of a pharmacy technician dispensing and informing patients. In the base-case analysis, we used government wage rates from Botswana;^{w6, w7} a range of $\pm 50\%$ was evaluated in the sensitivity analyses to ensure relevance to countries with different personnel costs and to cover uncertainty over testing and dispensing time. Drug costs were collected from the Technical Support Services, Botswana Ministry of Health and the International Drug Price Indicator Guide.^{w8, w9}

For the POC-test strategy, we added test costs and the cost of time required to conduct each test. Currently available POC tests cost between \$0.85 and \$7.00.^{7 18} We modelled test costs at between \$0.50 and \$4.00, as less expensive tests are likely to be available in the near future. Costs of staff training were not

included: Syndromic management requires frequent training and supervision of health personnel, and introducing POC tests for chlamydia should fit well into the ongoing activities of the national STI programmes. Discounting was not performed, as the time perspective was less than one year.

Sensitivity analyses

To test the robustness of model results, we undertook a range of sensitivity analyses. We first explored the consequences of parameter uncertainties in one-way sensitivity analyses, where one parameter at a time was varied up and down within the prespecified uncertainty bounds, while maintaining the others at their base-case values (tables 1 and 2). In these analyses, testing all new antenatal care attendees with a 50–85% POC test was compared with syndromic management in the same population using azithromycin as treatment.

We also performed probabilistic sensitivity analyses in which the model was run 10 000 times, allowing the effects of joint uncertainty across all the parameters of the model to be considered. Universal testing, first with a 50% sensitive and then with a 75% sensitive POC test, was compared with syndromic management in a population with 7.5% chlamydia prevalence, using azithromycin as the drug of choice. We adopted beta distributions for the probabilities to constrain the values between 0 and 1, and gamma distributions for the costs because of their skewness. The probabilities in the two strategies were linked to account for interdependencies.

Table 3 Testing all women with point-of-care (POC) tests compared with syndromic approach (SA)—according to treatment regimen, universal- or age-based management and test sensitivity: expected and incremental costs and effects per 1000 attendees included in the programme, and total programme costs and effects in a population of 100 000 antenatal care attendees*

Strategy		Cost (US\$)	Incremental cost (US\$)	Effectiveness (cured cases)			Incremental effectiveness (cured cases)	Cost per cured case (US\$)	Incremental cost per cured case (US\$)	Total programme costs (US\$)	Total programme effectiveness (cured cases)
				♀	♂	Total					
Erythromycin	Including all	SA	544	7	2	8		66		54 400	800
		POC 0.50	1104	15	6	22	13	51	42	110 400	2200
		POC 0.65	1124	20	8	28	20	40	29	112 400	2800
		POC 0.75	1137	23	9	32	24	35	25	113 700	3200
		POC 0.85	1150	26	10	36	28	32	22	115 000	3600
	Including <30	SA	548	8	2	10		54		40 600	700
		POC 0.50	1119	19	8	27	17	42	35	82 800	2000
		POC 0.65	1143	25	10	35	24	33	24	84 600	2600
		POC 0.75	1159	29	11	40	30	29	21	85 800	3000
		POC 0.85	1176	32	13	45	35	26	18	87 000	3300
Including <20	SA	562		14	4	17		32		11 000	300
		POC 0.50	1174	32	13	45	28	26	22	22 900	900
		POC 0.65	1215	42	17	59	41	21	16	23 700	1200
		POC 0.75	1242	49	19	68	50	18	14	24 200	1300
		POC 0.85	1269	55	22	77	59	17	12	24 700	1500
Azithromycin	Including all	SA	314	12	3	15		21		31 400	1500
		POC 0.50	1068	17	7	24	9	45	87	106 800	2400
		POC 0.65	1080	22	9	31	16	35	49	108 000	3100
		POC 0.75	1088	25	10	35	20	31	38	108 800	3500
		POC 0.85	1095	29	11	40	25	27	31	109 500	4000
	Including <30	SA	316	15	3	19		17		23 400	1400
		POC 0.50	1077	21	8	29	11	37	71	79 700	2100
		POC 0.65	1092	27	11	38	19	29	40	80 800	2800
		POC 0.75	1101	32	12	44	25	25	31	81 500	3300
		POC 0.85	1111	36	14	49	31	22	26	82 200	3600
Including <20	SA	324		26	5	32		10		6300	600
		POC 0.50	1110	36	14	50	18	22	43	21 600	1000
		POC 0.65	1130	46	18	65	33	18	25	22 000	1300
		POC 0.75	1150	54	21	75	43	15	19	22 400	1500
		POC 0.85	1170	61	23	84	53	14	16	22 800	1600

*Assuming that 19.5% of the attendees are less than 20 years of age and 74.0% are less than 30, and a *C trachomatis* prevalence of 15.8% among attendees less than 20 years of age and 9.3% among attendees less than 30 and 7.5% in the general population

Table 4 Number of female and male cases cured, number of patients overtreated, total costs, drug costs* and costs of drug wastage†: testing all women with a 50% or 75% sensitive point-of-care (POC) test compared with syndromic approach in a population of 100 000 antenatal care attendees‡

Strategy	Cases cured (n)	Over-treatment (n)	Cost (US\$)	Drug costs (US\$)	Drug wastage		
					(US\$)	% of drug costs	% of total costs
Syndromic approach	1500	29 900	31 400	31 400	28 200	90%	90%
Using POC tests (50% sensitivity)	2400	1800	106 800	5300	1500	29%	1%
Using POC tests (75% sensitivity)	3500	1900	108 800	7200	1600	22%	1%

*Azithromycin treatment of pregnant women, doxycycline treatment of partners.

†Cost of drug wastage = monetary cost of treating uninfected antenatal care attendees or uninfected partners.

‡Assuming a *C trachomatis* prevalence of 7.5% in the general population.

RESULTS

Health outcome and costs

Choice of antibiotics

In an antenatal care population of 100 000 attendees with a 7.5% chlamydia prevalence, syndromic management and treatment with erythromycin would entail a total cost of \$54 400 and result in 800 cases of chlamydia cured (\$66 per cured case) (table 3). Replacing erythromycin with azithromycin would entail a total cost of \$31 400 and result in 1500 cases cured (\$21 per cured case). In all scenarios, single-dose treatment with azithromycin implied a lower cost and greater effectiveness than did treatment with erythromycin (table 3). Therefore, in the next sections, we compare POC testing with the syndromic approach and universal versus age-based selective management using only the azithromycin treatment.

POC tests versus the syndromic approach

Testing all attendees with a 50% sensitive POC test priced at \$0.85 would cost \$106 800 and result in 2400 *C trachomatis* infections cured per 100 000 women (\$87 per additional case cured) (table 3). With increasing test sensitivity, the number of cases cured would increase further, while the cost of the programme would remain virtually unchanged, reducing the incremental cost per cured case.

Universal or selective management

Restricting syndromic management or testing for chlamydia to teenage attendees would entail the lowest cost per case cured: \$10 with the syndromic approach, \$22 with a 50% sensitive POC test, and \$15 with a 75% sensitive POC test (table 3). Selective compared with universal syndromic management implies lower programme costs but results in fewer infections cured—as fewer women are included—and the same applies to the use of POC tests (table 3). Reserving chlamydia treatment to teenagers would reduce the programme costs of syndromic management by 80%, but also reduce the number of cases cured by about 60%. Using a 75% sensitive POC test among teenagers, however, would be as effective as the syndromic management of chlamydia among all attendees, and the programme cost would be reduced from \$31 400 to \$22 400 (table 3).

Overtreatment and partner management

In a population of 100 000 pregnant women, syndromic management and azithromycin treatment would result in 1500 cured cases, although 29 900 individuals would be treated unnecessarily (table 4). The treatment costs would be \$31 400, 90% of which represents treatment of uninfected individuals. Introducing the testing of all attendees with a 50% or 75% sensitive POC test would result in 2400 or 3500 cured infections and 1800 or 1900 individuals unnecessarily treated. Furthermore, drug costs wasted on uninfected individuals

would be reduced by 95%. Selectively testing attendees less than 20 years of age with a 50% or 75% sensitive test would imply 1000 or 1500 cases of chlamydia cured and 300 individuals unnecessarily treated, reducing drug wastage to 1% of the current level.

With syndromic management, 140 of the estimated 6000 infected partners would be successfully treated (table 5). Using a 50% or 75% POC test would increase this number to 600 or 900, which also would reduce reinfection rates. The majority of attendees diagnosed as having syndromic approach are uninfected, and increasing partner attendance from the current 8.5% to 50% would result in 1200 more cases cured per 100 000 attendees—while 11 700 additional uninfected partners would be unnecessarily treated. Increasing partner attendance to 50% when using 50% or 75% sensitive POC tests would result in 1300 or 2100 more cases cured, while 700 or 900 additional partners would be treated unnecessarily.

Model uncertainty

In the one-way sensitivity analyses, the cost of the POC test had its greatest impact on the incremental cost per case cured of introducing POC tests (fig 2). High chlamydia prevalences result in the lowest incremental cost per additional case cured; decreasing from \$91.80 in populations with 3% prevalence to \$11.00 in populations with 31% prevalence (table 6). The probability of a partner being notified and attending healthcare with the POC-test strategy was also an important factor; the incremental cost per additional case cured ranged from \$69.90 with poor attendance to \$18.10 with optimal performance. For the remaining model parameters, realistic changes in values made little difference to the results.

As for the probabilistic sensitivity analyses, using POC tests was more effective and more costly than was the syndromic approach in practically all model iterations. The incremental number of infections cured with a 50% or 75% sensitive POC tests varied from –250 to 4100 or from 500 to 7200 per 100 000 women screened. The additional cost ranged from \$58 700 to \$94 700 or from \$60 800 to \$96 200. In Botswana, health authorities currently pay about \$66 per cured infection with *C trachomatis*. Adopting this willingness-to-pay threshold, replacing syndromic management with POC tests of all attendees had a 29% probability of being cost-effective with a 50% sensitive test and 94% with a 75% sensitive test (fig 3).

DISCUSSION

The results of this study indicate that there may be substantial benefits in changing current diagnostic and treatment strategies for chlamydia in antenatal care in sub-Saharan Africa. The prevailing syndromic management of all attendees appears to be the least effective; it incurs high costs per case cured and entails considerable overtreatment.

Table 5 Expected number of antenatal care attendees and their partners diagnosed, treated* and cured: testing all women with a 50% or 75% sensitive point-of-care test compared with syndromic approach in a population of 100 000 antenatal care attendees†

Strategy	Women diagnosed as having chlamydia (n)			Women prescribed treatment			Women initially cured (n)		Women re-infected		Partners notified and attended (n)				Partners treated (n)				Partners cured (n)			
	True pos	False pos	(n)	True pos	False pos	(n)	n	%	n	%	♀ TP	♂ TP	♀ FP	♂ FP	♀ CT+	♂ CT+	♀ CT-	♂ CT-	♀ TP	♂ TP	♀ FP	♂ FP

*Azithromycin treatment to pregnant women, doxycycline treatment to partners.

†Assuming a *C trachomatis* prevalence of 7.5% in the general population.♀, pregnant woman; ♂, male partner; CT+, *C trachomatis* infected; CT-, *C trachomatis* uninfected; FP, false positive; POC, using point-of-care tests; SA, syndromic approach; TP, true positive.

The study is limited by uncertainties in several of the model parameters. There is a paucity of high-quality studies providing data relevant for sub-Saharan Africa, and many probabilities are based partly on expert advice. For the POC-test strategy, the level of correct prescription, patient compliance and partner notification have a high degree of uncertainty, and were provided with broad uncertainty ranges. The sensitivity analyses show that partner notification with POC tests is important for the effectiveness of the strategy, also indicating the potential impact of strategies to improve partner notification. The cost of the POC test, which was the largest source of variation in the results, will be known by authorities who consider implementing a POC-test strategy.

Large evidence gaps and conflicting evidence exist regarding chlamydia-related complications and their economic consequences.^{19–20} Because of this lack of knowledge, especially for developing countries, cured infections was used as the effect measure; thus important health benefits of case detection and treatment are not captured in this analysis. Short-term outcomes are not ideal for making policy recommendations, but as the existing management requires substantial resources, information about possibilities for more advantageous resource allocation should be highly relevant to health policy makers. If successful chlamydia treatment reduces complications such as neonatal infections and postpartum infections, or reduces HIV transmission,^{4–5} it would strengthen the conclusions of this study.²¹

To our knowledge, no studies in resource-poor settings have explored the costs and health consequences of chlamydia management strategies in pregnancy. One study has estimated the incremental cost-effectiveness of using POC tests for chlamydia and gonorrhoea among sex workers in Benin. Compared with syndromic management, such tests were cost-effective, averting HIV infections and decreasing inappropriate treatment.¹⁸ Reviews of economic evaluations, mainly from developed countries, indicate that chlamydia screening is cost-effective, depending on prevalence; azithromycin is cost-effective; and partner notification is essential.^{21–22} The studies showed considerable variability with regard to probabilities used, complications and costing considered, and were hampered by methodological problems. The reviews point out the need for more data, particularly on the risk of complications.

We used a static model to evaluate the chlamydia management of antenatal care attendees, a relatively small, non-core group within the total population. Static models assume constant infection prevalence, even when strategies result in fewer or more infections being cured. In contrast, dynamic models incorporate the impact of changes in strategy on infection prevalence. In recent years, the use of dynamic models has been advocated.^{22–23} However, chlamydia programmes targeting pregnant women are less likely to lower prevalence, and have been specifically mentioned as an example in which static models may be the preferred option.²³

Botswana was used as the case for this analysis, but the model should be applicable to other sub-Saharan countries. In the majority of countries in the region, 70% or more of pregnant women attend antenatal care at least once,²⁴ providing a convenient framework for diagnosis, treatment and follow-up. Botswana is classified as “upper-middle income”, but the cost estimates will nevertheless be applicable to less wealthy settings with lower labour costs. The cost drivers in the model are POC tests and drugs purchased in international markets, and these prices will be relatively similar across countries. The sensitivity analysis indicates how higher or lower parameter values would change the results. To the extent that model data differ from those of other countries, the analysis can be revised on the basis of local data.

Figure 2 Tornado diagram summarising one-way sensitivity analyses in which testing all women with a POC test is compared with syndromic management of chlamydia among 100 000 antenatal care attendees.

Improving maternal and perinatal conditions and combatting HIV/AIDS received substantial attention in the Millennium Declaration.²⁵ It has been said that if countries are to have any chance of achieving their development goals, they need to re-evaluate existing strategies and replace less effective strategies with more effective ones.²⁶ Treatment of STIs is a strategy area that has already been prioritised in sub-Saharan Africa.²⁷ Chlamydia management in pregnancy is well within the scope of the development goals, and this study points to changes in diagnosis and treatment which may contribute to achieving these goals.

First, single-dose treatment with azithromycin should be preferred, providing lower costs and higher efficacy than does the week-long erythromycin regimen. Azithromycin is safe in pregnancy, with fewer side effects and less interaction with

other drugs.²⁸ Second, POC tests are necessary to improve effectiveness and reduce excessive overtreatment with the current management. In Botswana, the direct cost of introducing POC tests in antenatal care would increase the total health expenditure by 0.006%, an investment which may be more than offset by the reduced cost of the medical consequences of infection. Third, targeted partner notification is a good argument for introducing specific POC tests. Managing sexual partners of STI patients is essential to prevent reinfection, cure partners, break the chain of transmission and prevent complications;⁸ in studies from Africa, partner notification has been associated with potential harm, including domestic violence, and using an unspecific syndrome diagnosis as a basis for notifying partners is questionable.^{8, 29} If POC tests are introduced, however, patient-delivered medication or informa-

Table 6 Sensitivity analysis: cost per additional case cured with a POC test compared with syndromic approach under different assumptions about model parameters*

Variable	Parameter range		Cost (US\$) per additional case cured with POC-test strategy†	
	Lower bound	Upper bound	Lower bound	Upper bound
Probabilities common for both strategies				
<i>Chlamydia trachomatis</i> prevalence	0.03	0.31	91.80	11.00
<i>Chlamydia trachomatis</i> transmission probability	0.50	0.96	41.50	35.40
Compliance to azithromycin and drug effectiveness	0.88	1.00	40.90	36.40
Infected male with symptomatic infection	0.10	0.20	37.90	38.40
Symptomatic male seeking care independently	0.30	0.70	37.80	38.40
Symptomatic male cured independently	0.30	0.70	37.80	38.40
Probabilities in the syndromic approach strategy				
Syndromic approach sensitivity	0.36	0.62	32.40	46.50
Syndromic approach specificity	0.61	0.69	36.50	39.70
Prescription of treatment to test positive attendee	0.79	0.90	37.30	38.90
Male partner notified and attends clinic	0.06	0.11	37.00	39.30
Prescription of treatment to attending partner	0.76	1.00	36.1	40.70
Male compliant to doxycycline and drug effectiveness	0.60	1.00	37.20	39.10
Probabilities in the point-of-care strategy				
Point-of-care test sensitivity	0.50	0.85	86.80	31.30
Point-of-care test specificity	0.97	1.00	38.80	37.40
Prescription of treatment to test positive attendee	0.85	1.00	44.00	34.20
Male partner notified and attends clinic	0.09	0.65	69.90	18.10
Prescription of treatment to attending partner	0.85	1.00	38.90	37.70
Male compliant to doxycycline and drug effectiveness	0.80	1.00	41.60	35.20
Costs (\$/unit)				
Cost of point-of-care test	0.50	4.00	20.90	193.40
Cost of treatment with azithromycin	0.43	1.65	41.80	27.30
Cost of treatment with doxycycline	0.11	1.56	37.50	38.20
Cost of testing	0.08	0.25	34.00	42.20
Cost of dispensing	0.12	0.37	39.70	36.60

*Chlamydia management of all antenatal care attendees. First-line treatment regimens: azithromycin to pregnant women, doxycycline to males.

†Base-case results: The syndromic approach costs \$21.00 per case cured; using POC tests costs \$30.90 per case cured, and the incremental cost of testing all women with a POC test is \$38.10 per additional case cured.

Figure 3 Cost-effectiveness acceptability curves for testing all women with a POC test compared with syndromic management. The vertical line represents the current willingness to pay in Botswana (US\$66).

Key messages

- The use of single-dose azithromycin for the treatment of chlamydia in pregnancy was more effective and less costly than is the use of erythromycin.
- Moderately sensitive but highly specific POC tests may substantially improve case detection and treatment, and dramatically reduce the massive overtreatment that exists with syndromic approach.
- The use of POC tests will entail lowest incremental cost per case cured in high-prevalence settings, and their effectiveness will increase with optimal partner notification.
- Testing all teenagers with a 75% sensitive POC test was equally effective and less costly than the current syndromic management strategy was.

tion for partners should be considered.³⁰ Finally, the use of POC tests entails lowest incremental cost per case cured in populations with high prevalence. Adoption of age-restricted chlamydia treatment will entail lower programme costs and be more cost-effective than would the management of all pregnant women. Testing pregnant teenagers may be a feasible and reasonable way of introducing POC tests for chlamydia to antenatal care programmes in sub-Saharan Africa.

CONCLUSION

The results of this study indicate that sub-Saharan countries can substantially improve the management of chlamydia in antenatal care. Changes in diagnostic and treatment strategies may improve maternal and infant health as well as resource use.

ACKNOWLEDGEMENTS

The authors thank the Health Research Unit, Ministry of Health, for their valuable contributions to the formal and organisational aspects of the study. We also want to thank the staff at the government Clinics and at The National Health Laboratory for their cooperation, Mafizur Rahman for his contributions during the fieldwork, Elise Klouman for thoughtful input and Torbjørn Fosen Wisløff for technical assistance.

CONTRIBUTIONS

MR and ISK designed the decision analytical model. Data collection was undertaken by MR, FH and TWS; the epidemiological study in Gaborone was planned and conducted by MR, MV, JS and PH. Data were analysed by MR, and interpreted by MR and ISK. The manuscript was written by M Romoren, and all authors have proved the final version.

Authors' affiliations

M Romoren, J Sundby, P Hjortdahl, I S Kristiansen, Faculty of Medicine, University of Oslo, Norway
F Hussein, T W Steen, Department of HIV/AIDS Prevention and Care, Ministry of Health, Gaborone, Botswana
M Velauthapillai, National Health Laboratory, Ministry of Health, Gaborone, Botswana

Funding: The study in Botswana was funded by The Health Sector Agreement between Norway and Botswana. M R was funded by a grant from the Norwegian Research Council. The funding sources were not involved in the study.

Competing interests: None.

REFERENCES

- 1 WHO. Global prevalence and incidence of selected curable sexually transmitted infections. Geneva: WHO, 2001. <http://www.who.int/hiv/pub/sti/pub7/en/> (accessed 16 Oct 2007).
- 2 Over M, Piot P. HIV infections and sexually transmitted diseases. In: Jamison DT, Malsey HW, Measham AR, Bobadilla JL, eds. *Disease control priorities in developing countries*. Oxford: Oxford University Press, 1993:455–527.
- 3 Mullick S, Watson-Jones D, Bekinska M, et al. Sexually transmitted infections in pregnancy: prevalence, impact on pregnancy outcomes, and approach to treatment in developing countries. *Sex Transm Infect* 2005;**81**:294–302.
- 4 Sexton J, Garnett G, Rottingen JA. Metaanalysis and meta-regression in interpreting study variability in the impact of sexually transmitted diseases on susceptibility to HIV infection. *Sex Transm Dis* 2005;**32**:351–7.
- 5 UNAIDS/WHO. Consultation on STD interventions for preventing HIV: what is the evidence? Geneva: UNAIDS/WHO, 2000. http://data.unaids.org/Publications/IRC-pub01/JC300-ConsultSTD_en.pdf (accessed 16 Oct 2007).
- 6 WHO. Guidelines for the management of sexually transmitted infections. Geneva: WHO, 2003. <http://www.who.int/hiv/pub/sti/en/STIGuidelines2003.pdf> (accessed 19 Oct 2007).
- 7 Vuylsteke B. Current status of syndromic management of sexually transmitted infections in developing countries. *Sex Transm Infect* 2004;**80**:333–4.
- 8 Mayaud P, Mabey D. Approaches to the control of sexually transmitted infections in developing countries: old problems and modern challenges. *Sex Transm Infect* 2004;**80**:174–82.
- 9 Mabey D, Peeling RW, Perkins MD. Rapid and simple point of care diagnostics for STIs. *Sex Transm Infect* 2001;**77**:397–8.
- 10 Yin Y-P, Peeling RW, Chen X-S, et al. Clinic-based evaluation of Clearview Chlamydia MF for detection of *Chlamydia trachomatis* in vaginal and cervical specimens from women at high-risk in China. *Sex Transm Infect* 2006;**82**:33–7.
- 11 Cates W Jr. Contraception, unintended pregnancies, and sexually transmitted diseases: why isn't a simple solution possible? *Am J Epidemiol* 1996;**143**:311–8.
- 12 Romoren M, Sundby J, Velauthapillai M, et al. Chlamydia and gonorrhoea in pregnant Botswana women: Time to discard the syndromic approach? *BMC Infect Dis* 2007;7.
- 13 Ministry of Health. *Botswana second generation HIV/AIDS surveillance 2006*. Gaborone, Botswana: Ministry of Health, 2007.
- 14 Romoren M, Rahman M, Sundby J, et al. Chlamydia and gonorrhoea in pregnancy: effectiveness of diagnosis and treatment in Botswana. *Sex Transm Infect* 2004;**80**:395–400.
- 15 Romoren M, Hussein F, Steen TW, et al. Costs and health consequences of chlamydia management strategies in pregnant women in sub-Saharan Africa. Technical Report, 2007. http://www.hero.uio.no/publicat/2007/HERO2007_10.pdf (accessed 19 Oct 2007).
- 16 Dalabatta GA, Gerbase AC, Holmes KK. Problems, solutions, and challenges in syndromic management of sexually transmitted diseases. *Sex Transm Infect* 1998;**74**(Suppl 1):1–11S.
- 17 Peeling RW, Holmes KK, Mabey D, et al. Rapid tests for sexually transmitted infections (STIs): the way forward. *Sex Transm Infect* 2006;**82**(Suppl 5):1–6S.
- 18 Vickerman P, Watts C, Peeling RW, et al. Modelling the cost effectiveness of rapid point of care diagnostic tests for the control of HIV and other sexually transmitted infections among female sex workers. *Sex Transm Infect* 2006;**82**:403–12.
- 19 Blas MM, Canchihuaman FA, Alva IE, et al. Pregnancy outcomes in women infected with *Chlamydia trachomatis*: a population-based cohort study in Washington State. *Sex Transm Infect* 2007;**83**:314–18.
- 20 van Valkengoed IG, Morre SA, van den Brule AJ, et al. Overestimation of complication rates in evaluations of *Chlamydia trachomatis* screening programmes—implications for cost-effectiveness analyses. *Int J Epidemiol* 2004;**33**:416–25.
- 21 Welte R, Jager H, Postma MJ. Cost-effectiveness of screening for genital *Chlamydia trachomatis*. *Expert Rev. Pharmacoeconomics Outcomes Res* 2001;**1**:145–56.
- 22 Roberts TE, Robinson S, Barton P, et al. Screening for *Chlamydia trachomatis*: a systematic review of the economic evaluations and modelling. *Sex Transm Infect* 2006;**82**:193–200.
- 23 Welte R, Postma M, Leidl R, et al. Costs and effects of chlamydial screening: dynamic versus static modeling. *Sex Transm Dis* 2005;**32**:474–83.
- 24 WHO. Antenatal care in developing countries: promises, achievements and missed opportunities: analysis of trends, levels and differentials, 1990–2001. Geneva: WHO, 2003. http://www.who.int/reproductive-health/docs/antenatal_care.pdf (accessed 19 Oct 2007).

- 25 **WHO**. Health and the millennium development goals. Geneva: WHO, 2005. http://www.who.int/hdp/publications/mdg_en.pdf (accessed 16 Oct 2007).
- 26 **Evans DB**, Adam T, Edejer TT, *et al*. Time to reassess strategies for improving health in developing countries. *BMJ* 2005;**331**:1133–6.
- 27 **Hogan DR**, Baltussen R, Hayashi C, *et al*. Cost effectiveness analysis of strategies to combat HIV/AIDS in developing countries. *BMJ* 2005;**331**:1431–7.
- 28 **Centers for Disease Control and Prevention**. Sexually transmitted diseases treatment guidelines. Atlanta, GA: Centers for Disease Control and Prevention, 2006. <http://www.cdc.gov/std/treatment/2006/rr5511.pdf> (accessed 16 Oct 2007).
- 29 **Hawkes S**, Mabey D, Mayaud P. Partner notification for the control of sexually transmitted infections. *BMJ* 2003;**327**:633–4.
- 30 **Trelle S**, Shang A, Nartey L, *et al*. Improved effectiveness of partner notification for patients with sexually transmitted infections: systematic review. *BMJ* 2007;**334**:354–7.

Take advantage of BMJ Journals' remarkable catalogue of titles with Related Collections

No busy professional has time to browse through all pertinent journals to find relevant articles, but with Related Collections you no longer have to. Follow the "Related Collections" link from any article and use the "Show Collections from other Journals" to expand your search across all BMJ Journals. Or simply follow the "Browse by topic" link on the home page. By setting up your own collections and receiving email alerts every time an article is added to your chosen area, you can build up your own significant body of knowledge.