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Research Article

Helicobacter Pylori (*H. pylori*) Eradication Rates and Antibiotic Resistance Patterns in Nigeria: A Systematic Review and Meta-Analysis

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Abstract

Background: Nigeria has the highest global *Helicobacter pylori* infection prevalence rate. The increasing resistance of *H. pylori* to antibiotic treatment with concomitant increasing eradication failure is a growing global concern. We aimed to evaluate Nigeria's *H. pylori* eradication rates and antibiotic resistance patterns.

Methods: We systematically searched PubMed, EMBASE, Global Index Medicus, Africa-Wide Information, and African Journals Online for *H. pylori* studies conducted on humans and published in English, evaluating eradication rates and antibiotic resistance patterns. Meta-analysis was performed to estimate the proportion, pooled proportions, and their respective 95% Confidence Interval (CI). We compared 14 days of triple therapy with 7 or 10-s therapies. I^2 was calculated to examine statistical heterogeneity.

Results: Of 521 studies screened, four were included for *H. pylori* eradication and 11 for antibiotic resistance. The overall *H. pylori* eradication rate was 63% (95% CI [50%-76%], n=361, I2 = 94.79%), but 71% (95% CI [44%-99%] in patients taking a Rabeprazole/Amoxicillin/Clarithromycin (RAC) regimen. A 14-day triple therapy was more effective than a 7-day or 10-day triple therapy, with an RR of 1.47 [1.32-1.64]. The most common antibiotic resistance rates were for metronidazole (86%, 95% CI [72%-99%], n=2528, I2=99.6%) and amoxicillin (71%, 95% CI [54%-89%], n=1981, I2=99.3%).

Conclusion: The 14-day triple therapies performed better than the seven- and ten-day regimens, with the 14-day proton pump inhibitor, amoxicillin, and clarithromycin combination regimen being the most efficacious triple therapy. Resistance to the key antimicrobial medications used in Nigeria to treat *H. pylori* infection is alarmingly high, yet eradication rates remain relatively reasonable (though sub-optimal). The disconnect between these two phenomena is worthy of further investigation.

Keywords: *Helicobacter pylori* (*H. pylori*); Eradication; Antibiotic; Resistance; Nigeria

Introduction

Helicobacter pylori (*H. pylori*) are a gram-negative, flagellated, microaerophilic helical-shaped bacterium that has chronically infected more than 50% of the world's population [1]. It is classified as a class one carcinogen and one of the most common chronic bacterial infections in humans. It affects approximately 4.4 billion people worldwide, with 28% to 84% prevalence in different populations [2]. *H. pylori* infection eradication rates and antibiotic resistance patterns vary among different global geographical regions, which largely mirror the type and quantity of antibiotics used in particular population [3,4]. Eradication of *H. pylori* is the most effective means to cure and prevent recurrence of peptic ulcer disease and Mucosa-Associated Lymphoid Tissue (MALT) lymphoma. The risk of gastric cancer is related to the severity and extent of gastric atrophy, intestinal metaplasia, and dysplasia. Eradication of *H. pylori* has been found beneficial in preventing the progression of atrophy and intestinal metaplasia of the gastric mucosa, leading to an approximately 50% reduction in the risk of gastric cancer development [5]. *H pylori* eradication requires the combination of antibiotics with acid-suppressive medication, as no single agent is sufficient to eradicate the organism. An ideal therapy for treating *H. pylori* should lead to an eradication rate above 90% [6].

Globally, there has been a substantial decline in *H. pylori* eradication rates over the years due to antibiotic resistance [7,8]. Resistance to previously efficacious antibiotics is increasing worldwide

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and is associated with low eradication rates and treatment failure. *H. pylori* antibiotic resistance is on the increase in Africa, and Nigeria is especially noteworthy since it already grapples with alarming *H. pylori* infection prevalence rates as high as 73% to 87% in its various regions [3].

In developing countries, triple or quadruple therapy is recognized as a first-line regimen, while the second-line option includes levofloxacin, rifabutin, or furazolidone-containing regimen [4]. Triple therapy consists of a proton pump inhibitor and two antibiotics: amoxicillin and clarithromycin, or metronidazole and clarithromycin, while quadruple therapy consists of a proton pump inhibitor, bismuth, and two antibiotics: typically, amoxicillin plus clarithromycin, or metronidazole plus tetracycline [9].

Other therapies that have been used in many countries include a non-bismuth quadruple therapy (concomitant therapy) that comprises a proton pump inhibitor, amoxicillin, metronidazole, and clarithromycin given for 10 or 14 days, and sequential therapy - which consists of five days of a proton pump inhibitor and amoxicillin followed by five days of the same proton pump inhibitor, with metronidazole or tinidazole, and clarithromycin [10].

Several salvage therapies have also been described for refractory cases. They generally include a quinolone or rifabutin in combination with amoxicillin and either a proton pump inhibitor or Potassium-Competitive Acid Blocker (PCAB) [11].

Materials and Methods

Search strategy and data sources

We searched PubMed, Embase, Global Index Medicus (WHO), and Africa-Wide Information using controlled vocabulary and text word search terms, combining the concepts of *H. pylori* and Nigeria, looking for studies that reported numeric data on eradication and/or antibiotic resistance rates in patients with *H. pylori* infection. African Journals Online (AJOL) was searched as a supplemental source. No limits or filters were applied. Searches were conducted on May 11, 2021. The results were exported to EndNote 20 (Clavirate, Philadelphia), de-duplicated, and uploaded to Covidence for blinded screening by two independent reviewers. All authors in this manuscript adjudicated disputes. This systematic review and meta-analysis are reported following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Figure 1) [12].

Study selection and data extraction

The review included all full articles that investigated *H. pylori* eradication rates with a triple regimen treatment and/or antibiotic resistance in Nigeria, conducted on humans and published in English. For both *H. pylori* eradication and antibiotics resistance studies, we collected data on study methodology, year of publication, location and geographic area, study population size, mean age, range, and gender distribution. In addition, for the *H. pylori* eradication studies, we collected data on the triple regimens and their dosages, eradication rates (%), interval of treatment, duration of therapy, and treatment by per protocol or Intention-To-Treat (ITT). For the antibiotic resistance studies, we collected data on the antibiotics (amoxicillin, ciprofloxacin, clarithromycin, erythromycin, metronidazole, rifampicin, tetracycline, piperacillin, ampicillin, cefuroxime, levofloxacin, tinidazole, and cefuroxime) resistance proportion in the patients in each study.

The susceptibility of isolates to antibiotics was tested using either

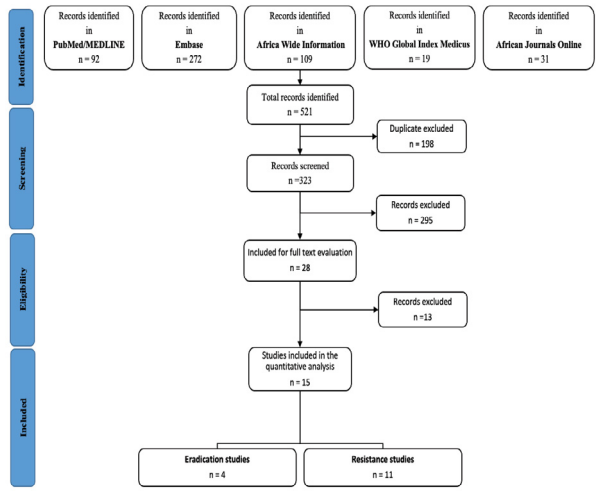

Figure 1: PRISMA flow diagram for systematic literature review of *H. pylori* eradication and antibiotics resistance in Nigeria. PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

the disc diffusion assay with Campy Gen System (Oxoid Ltd-disc diffusion), according to the methodology described by Lopez Brea and Alarcon [3]. The resistance breakpoint was as defined by the National Committee for Clinical Laboratory Standards or by the European Committee on Antimicrobial Susceptibility Testing (EUCAST), and Minimum Inhibitory Concentrations (MIC) were used as the clinical breakpoint [3].

Data synthesis analysis

Categorical data points were summarized as counts and proportions extracted from the eligible publications on the *H. pylori* eradication and antibiotic resistance studies, respectively. Meta-analysis was performed to report proportion, pooled proportions, and their respective 95% Confidence Interval (CI) using the statistical jamovi version 2.2.5 [13,14]. Applying a random-effects meta-analysis model with the DerSimoniane Laird method and using the DerSimonian Laird model for measuring raw proportions [15]. The *H. pylori* eradication studies analysis was supplemented by estimated Relative Risk (RR) comparing Rabeprazole, Amoxicillin, and Clarithromycin (RAC) triple regimen with other triple regimens that included Esomeprazole, Clarithromycin, and Amoxicillin (ECA), Omeprazole, Clarithromycin, and Amoxicillin (OCA), Omeprazole, Tinidazole, and clarithromycin (OTC), Rabeprazole, Amoxicillin, and Levofloxacin (RAL), Rabeprazole, Amoxicillin and Metronidazole (RAM), and Rabeprazole, Clarithromycin, and Metronidazole (RCM). We also compared Long-Duration Treatment (LDT), defined as a 14-day therapy, with Short-Duration Treatment (SDT) as a 7 or 10-day treatment.

I^2 was calculated to examine statistical heterogeneity. Its value ranged between 0% and 100%, representing the proportion of inter-study variability attributed to heterogeneity rather than chance (I^2 >50% was considered high heterogeneity). The Cochran's Q test was also used to determine whether there are differences between primary studies or if the variation seen is due to chance [16]. The proportions and the pooled proportion, with their respective 95% CI, were illustrated as a Forest plot showing the weighted proportion from each study represented by a bullet point [17]. The relative size of these bullets represents a study's weight in generating the pooled

meta-analytic result using a random effect model [18]. The results have been sorted by the observed effect size of each study.

Publication bias was assessed using the Rosenthal approach to the Fail-safe N (file draw analysis), with Egger's regression asymmetry test and Kendall's Tau test for rank correlation test for funnel plot asymmetry [19].

Results

Eradication rates

The total sample size of the four studies that evaluated *H. pylori* eradication rates was 341 participants for triple therapy. Three of the four studies indicated the sex of the participants with a male-to-female ratio of 1:1.2. The age of the participants ranged from 13 to 84 years (mean age 44 years ± 12.6). The average eradication rate of triple therapy by protocol analysis (PP) was 61.5%, while per Intention to Treat (ITT) was 51.0%. No studies reported any other treatment options (such as quadruple or sequential), Table 1.

The meta-analysis showed that overall, 63.1% of the patients had *H. pylori* eradicated (95%CI [50.31%-75.80%], n=361, I2 = 94.79%), ranging from 30.0% [21%-39%] to 89% [81%-98%] across all studies, Figure 2. The highest eradication rate was seen in patients on Rabeprazole/Amoxicillin/Clarithromycin (RAC) regimen 71.14% 95%CI [43.76%-98.49%], and ranging from 30% [21%-39%] to 89% [81%-98%]. All other regimens [Rabeprazole, Amoxicillin, and Metronidazole (RAM), Omeprazole, Tinidazole, and Clarithromycin (OTC), Rabeprazole, Amoxicillin, and Levofloxacin (RAL), Omeprazole, Clarithromycin and Amoxicillin (OCA), Esomeprazole, Clarithromycin, and Amoxicillin (ECA), and Rabeprazole, Clarithromycin and Metronidazole (RCM)] presented an estimated pooled eradication rates of 57.52% [46.16%-68.88%], ranging from 44% [35%-54] to 78% [70%-86%]. The triple RAC regimen was 18% more effective than OTC, RAL, OCA, ECA, and RCM with a Relative Risk (RR) of 1.18 95% CI [1.04-1.33], Figure 3. Long-duration triple therapy was associated with a higher eradication rate of 80.19% 95%CI [74.76%-85.62%], and ranking from 78% [72%-85%] to 87% [78%-97%], compared to short treatment 58.05% [44.17%-71.93%], and ranging from 30% [21%-39%] to 89% [81%-98%]. Long-duration triple therapy was 47% more effective, with a RR of 1.47 [1.32-1.64], Figure 4 and 5.

Antibiotic resistance

A total of 11 studies included data on antibiotic resistance rates, with a total patient sample size of 1406. Seven studies indicated the sex of the participants with a male-to-female ratio of 1:1.3. The participants ranged from 13 to 90 years (mean age of 38.1 years+11.1). The most commonly studied antibiotics were metronidazole and tetracycline. Others were amoxicillin, clarithromycin, ciprofloxacin, erythromycin, rifampicin, piperacillin, ampicillin, and cefuroxime. *H. pylori* resistance rates to the most commonly studied antibiotics were as follows; metronidazole-91.6%, tetracycline-56.0%, amoxicillin-64.3%, clarithromycin- 42.6% and ciprofloxacin- 22.3%. *H. pylori* was 100% resistant to metronidazole in 5 out of 11 studies and 100% resistant to tetracycline in 4 out of 11 studies, Table 2.

The most common antibiotic resistance rates were to metronidazole (86% 95%CI [72%-99%], n=2528, I^2=99.6%), ranging from 40% [27%-53%] to 100% [100%-100%], amoxicillin (71% 95% CI [54%-89%], n=1981, I^2=99.3%) range 33% [29%-37%] to 99% [97%-102%]; tetracycline (58% 95%CI [31%-84%], n=2268, I^2=99.9%), range 5% [3%-6%] to 100% [99%-100%]; and clarithromycin (43% 95%CI [14%-72%], n=1488, I^2=99.6%), range 8% [0%-15%] to 98% [94%-103%].

The Rosenthal approach to the Fail-safe N shows possible publication bias for estimated eradication and antibiotic resistance rates, respectively, with p-value<0.0001 for all cases. The Egger's regression asymmetry test and Kendall's Tau test for rank correlation test for funnel plot asymmetry did not find any asymmetry due to publication bias for eradication rate (p-value=0.5885 and 0.5832, respectively), and also for amoxicillin (p-value=0.61220and 0.7790), clarithromycin (p-value=0.7726 and 0.6332), and tetracycline (p-value=0.4843and 0.6787). There was an asymmetry due to the publication bias for metronidazole (Egger's regression asymmetry test, p-value=0.0264; and Kendall's Tau test, p-value=0.0010). Sensitivity analyses were conducted to investigate each study's influence by excluding and replacing one study at a time from the meta-analysis and evaluating the pooled estimate for the other studies. We found no noteworthy changes from the pooled estimates when other publications were removed.

Discussion

The burden of *H. pylori* infection in Nigeria is fueled by increasing *H. pylori* resistance to the previously efficacious antibiotics and concomitant poor eradication rates, acting in synergy with poor sanitation, overcrowding, and perpetuation of infection transmission by those infected with *H. pylori*. The age range of the participants in

Table 1: Triple therapy for H. pylori eradication in Nigeria, 2005-2019.

Study author (year)	Age	Mean age	Gender		Sample size	Regimen	Dosage	Duration of treatment (days)	Eradication rates (%)	ITT (%)
			Male	Female						
Abdulkareem et al. (2019)	18-53	35.7 + 8	65	95	160	RAC	20 mg, 1 g, 500 mg	14	78	72.1
Onyekwere et al. (2014)	13-80	47.7 + 16.8	18	29	47	RAC	20 mg, 1 g, 500 mg	7	88.9	
						RAC	20 mg, 1 g, 500 mg	10	86.2	
Salawu et al. (2005)	NA	38.7 + 16.1	27	23	50	ECA	20 mg, 500 mg, 1 g	7	70	
						OCA	20 mg, 500 mg, 1 g	7	55	
Olusoji et al. (2015)	18-50	37.8 + 12.88	34	70	104	RCM	20 mg, 500 mg, 400 mg	14	77.8	41.2
						RAL	20 mg, 1 g, 500 mg	14	53.3	35
						RAM	20 mg, 1 g, 400 mg	14	44.4	33.3
						OTC	20 mg, 500 mg, 250 mg	14	44.4	23.5
						RAC	20 mg, 1 g, 500 mg	14	30	23.1

N/A: Not Available; PP: Per Protocol; ITT: Intention to Treat; OCM: Omeprazole, Clarithromycin and Metronidazole; RAC: Rabeprazole, Amoxicillin, and Clarithromycin; RCM: Rabeprazole, Amoxicillin and Metronidazole; RAL: Rabeprazole, Amoxicillin, and Levofloxacin; RAM: Rabeprazole, Amoxicillin and Metronidazole. OTC: Omeprazole, Tinidazole, and Clarithromycin

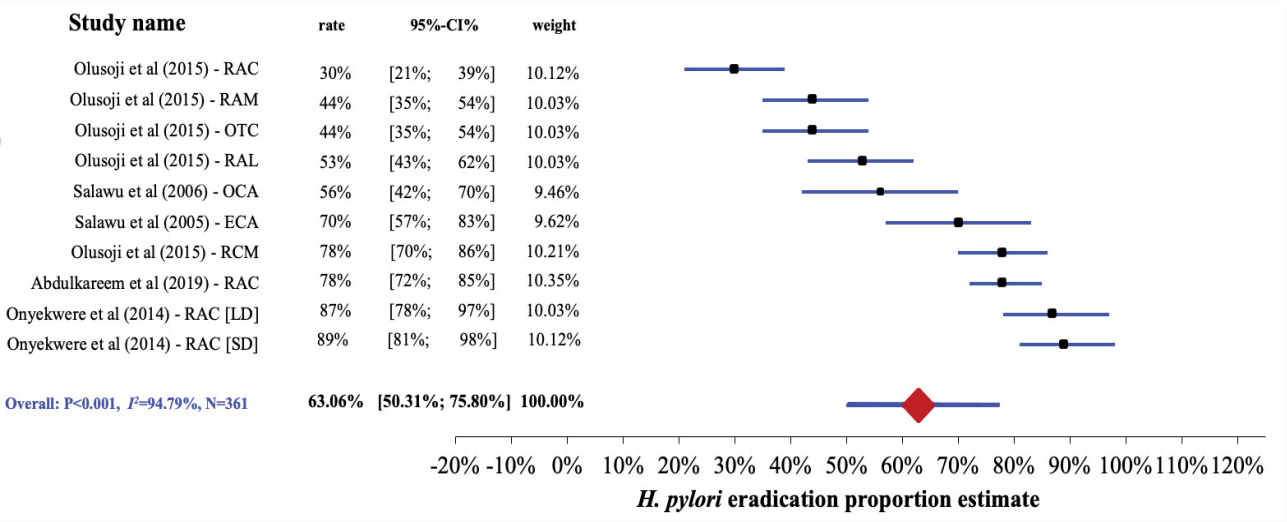

Figure 2: *H. pylori* eradication rates in Nigeria, 2005-2019. LD is a Long-duration treatment defined as 14 days, and SD is defined as Short-duration treatment as 7 or 10 days. Notes: Tick squares and the corresponding lines represent the point estimates and 95% confidence interval of H. pylori eradication per study. The size of these black squares represents a study's weight in generating the pooled meta-analytic result using a random effect model. The results have been sorted by the observed effect size of each study. The red diamond is the pooled estimate.

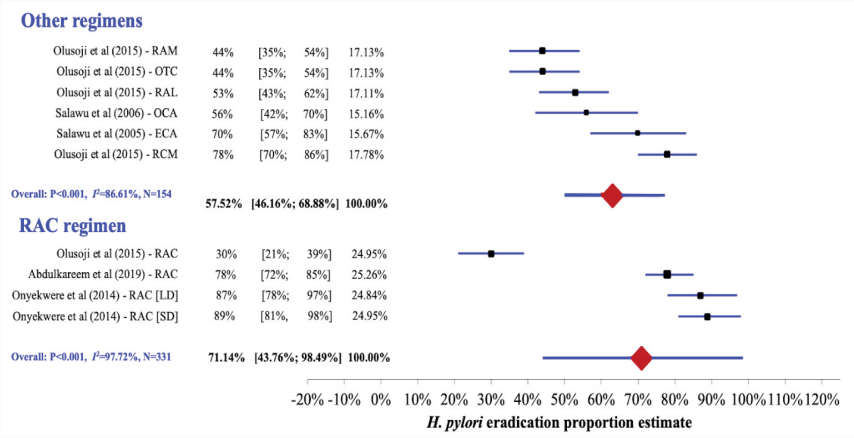

Figure 3: RAC compared to other regimens among H. pylori eradication rates in Nigeria, 2005-2019.
A: Amoxicillin; C: Clarithromycin; E: Esomeprazole; L: Levofloxacin; M: Metronidazole; O: Omeprazole; R: Rabeprazole; RE: Random Effect; RR: Relative-Risk; T: Tinidazole
Notes: LD is a Long-duration treatment defined as 14 or 10 days of treatment, and SD is a Short-duration treatment defined as 7 or 10 days. The regimens included RAC, ECA, OCA, OTC, RAL, RAM, and RCM. The RR estimated comparing the RAC triple regimen with other regimens is 1.18 95% CI [1.04-1.33], and comparing long with short duration treatment is 1.47 95% CI [1.32-1.64]. The black squares and their corresponding lines represent the point estimates and 95% confidence interval of H. pylori eradication per study, respectively. The relative size of these black squares represents a study's weight in generating the pooled meta-analytic result; using a random effect, results have been sorted by the observed effect size of each study. The red diamond is the pooled estimate.

Table 2: *H. pylori* antibiotic resistance pattern in Nigeria, 2005-12019.

Study author (year)	Age (min, max)	Mean age	Gender		Sample size
			Male	Female	
Abdul et al. (2005)	20-73	49.3+16.78	12	8	20
Oyedeji et al. (2009)	NA	NA	NA	NA	186
Aboderin et al. (2007)	20-73	48.6 ± 16.23	16	16	32
Tolulope et al. (2020)	NA	NA	NA	NA	492
Smith et al. (2001)	NA	NA	NA	NA	56
Ute Harrison et al. (2017)	10-110	50 ± 10	261	315	577
Ani et al. (1999)	NA	NA	22	33	55
Oyedeji et al. (2018)	001- 16	14.5+ 0.5	143	117	260
Bello et al. (2019)	18-84	41.2+15.3	136	170	306
Bolanle et al. (2012)	13-90	NA	17	35	52
Palamides et al. (2020)	NA	NA	NA	NA	30

these studies clearly shows that *H. pylori* infection cuts across all age groups. The association between gender and *H. pylori* resistance to antibiotics could not be inferred, as none of the studies compared antibiotic resistance in males and females. The significant number of female participants could be a reflection of the lopsided burden of *H. pylori* infection in the female gender but could as well result from their increased interest in accessing health care or participating in research.

The resistance of *H. pylori* to antibiotic treatment and poor eradication rates are a growing global concern [20]. and more problematic in Africa, with a massive burden of *H. pylori* infection, especially in Nigeria, with the highest *H. pylori* infection prevalence. Some prior studies in Nigeria had documented 100% antibiotic resistance to some of the previously efficacious antibiotics used

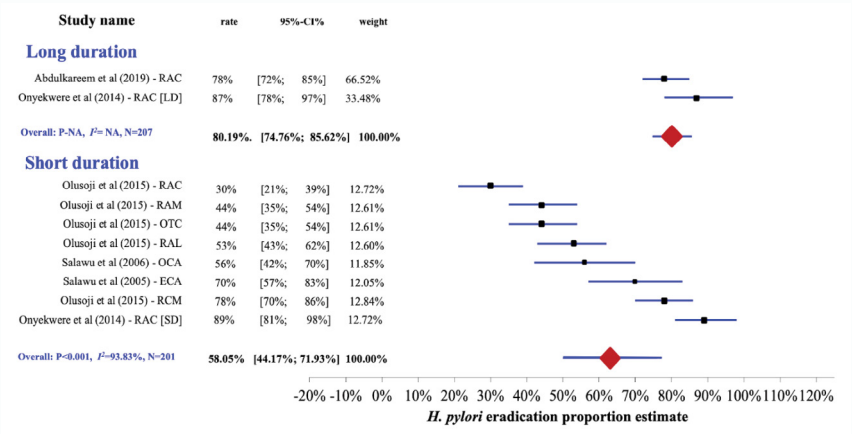

Figure 4: Short and long treatment duration among *H. Pylori* eradication rates in Nigeria, 2005-2019.
A: Amoxicillin; C: Clarithromycin; E: Esomeprazole; L: Levofloxacin; M: Metronidazole; O: Omeprazole; R: Rabeprazole; RE: Random Effect; T: Tinidazole
Notes: LD is a Long-duration treatment defined as 14 days, and SD is a Short-duration treatment as 7 or 10 days of treatment. The black squares and their corresponding lines represent the point estimates and 95% confidence interval of *H. Pylori* eradication per study, respectively. The relative size of these black squares represents a study's weight in generating the pooled meta-analytic result using a random effect model. The results have been sorted by the observed effect size of each study. The red diamond is the pooled estimate.

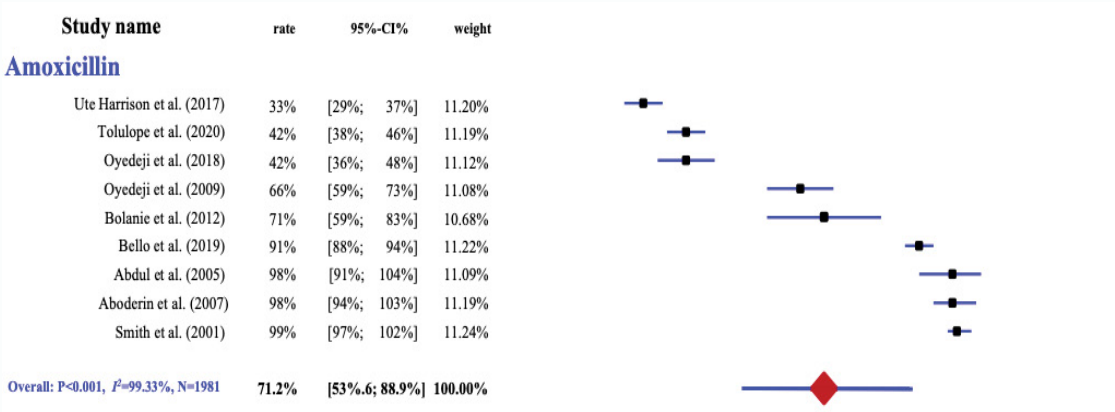

Figure 5(A): Antibiotic resistance proportion estimate among *H. pylori* patients, in Nigeria, 2005-2019.

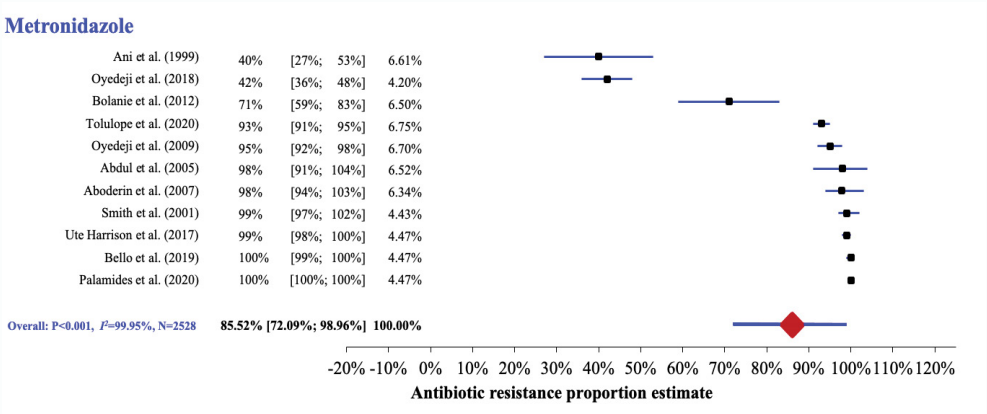

Figure 5(B): Antibiotic resistance proportion estimate among H. pylori patients, in Nigeria, 2005-2019.

in treating *H. pylori*, a reason for marked treatment failure. The studies showed significant antibiotic resistance to the commonly used eradication agents. This finding may indicate a loss of efficacy of the currently prescribed therapeutic regimens for eradicating *H. pylori*. The most frequently used antibiotics for eradicating *H. pylori*, namely amoxicillin, clarithromycin, metronidazole, and tetracycline, have shown high *H. pylori* resistance rates. Antibiotic resistance was 100% in 45.5% of the studies that assessed resistance

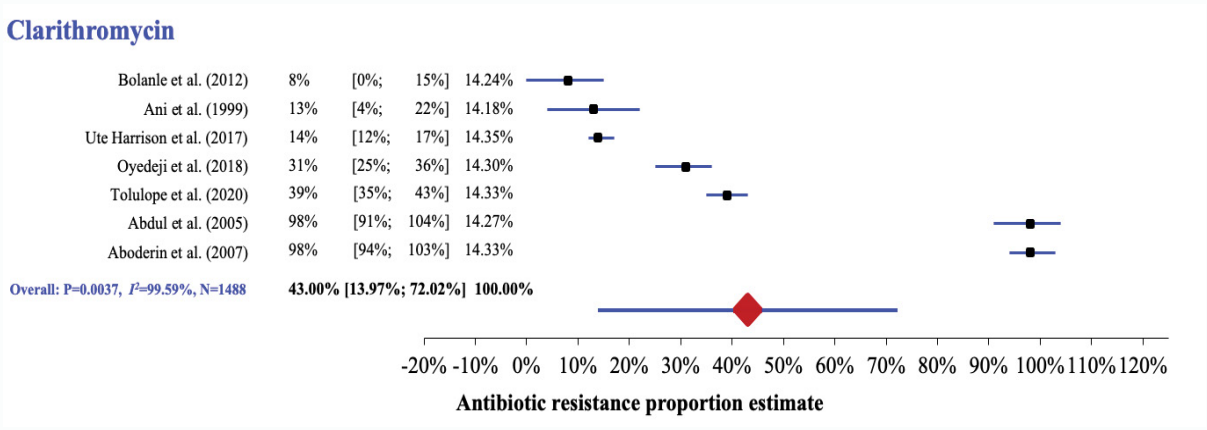

Figure 5(C): Antibiotic resistance proportion estimate among *H. pylori* patients, in Nigeria, 2005-2019.

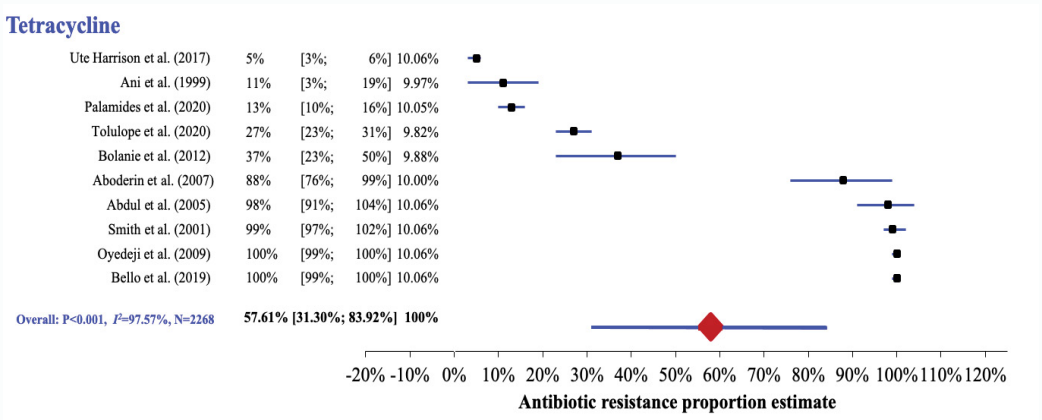

Figure 5(D): Antibiotic resistance proportion estimate among H. pylori patients, in Nigeria, 2005-2019.
Notes: The black squares and their corresponding lines represent the point estimates and 95% confidence interval of each specific antibiotic resistance among H. pylori patients, respectively. The relative size of these black squares represents a study's weight in generating the pooled meta-analytic result using a random effect model. The results have been sorted by the observed effect size of each study. The red diamond is the pooled estimate.

to metronidazole (5 out of 11) and 100% resistance in 36.4% of the studies that assessed resistance to tetracycline (4 out of 11), a reason for the suboptimal eradication rates. The amoxicillin resistance rate in Nigeria is 64.3% but relatively comparable to the pooled amoxicillin resistance in Africa, 38% (32-45). The amoxicillin resistance rates in Nigeria and many other countries in Africa seem extraordinarily high and out of the range recorded in other continents. Amoxicillin resistance in the United States and Europe was 1.2 % (<5%). Clarithromycin and metronidazole resistance were 22.2% and 69.2%, respectively, relatively comparable to the values of clarithromycin and metronidazole resistance in other regions [21]. Another *H. pylori* antibiotic resistance study conducted in the United States of America by Ho et al. [22] yielded a pooled resistance prevalence of 42.1% (95% CI 27.3%-58.6%) for metronidazole, 37.6% (95% CI 26.3%-50.4%) for levofloxacin, 31.5% (95% CI 23.6%-40.6%) for clarithromycin, 2.6% (95% CI 1.4%-5.0%) for amoxicillin, 0.87% (95% CI 0.2%-3.8%) for tetracycline, and 0.17% (1/605) (95% CI 0.00%-10.9%) for rifabutin. Further investigation is necessary to understand how much this data reflects methodological issues *vs.* true differences on amoxicillin resistance and susceptibility.

In Europe, the resistance of *H. pylori* to clarithromycin and levofloxacin has been linked to the widespread use of macrolides and fluoroquinolones, respectively [23]. The geographical variation in the resistance of *H. pylori* to antibiotics is believed to stem from the magnitude of antibiotic use within a population [24]. In Nigeria, amoxicillin, metronidazole, tetracycline, and erythromycin are widely used for self-medication, aggravated by the ineffective drug control policy to curtail free access to over-the-counter procurement of antibiotics. Ghotaslou et al. [25] noted that metronidazole and clarithromycin resistance were markedly related to the prevalence of previous use of macrolide and metronidazole, respectively. Similar to the high metronidazole resistance in this review, other prior studies have also documented high *H. pylori* resistance to metronidazole. Megraud et al. [23] found a significant association between metronidazole resistance in *H. pylori* treatment and the previous use of nitroimidazole. The pooled global prevalence of metronidazole resistance is 43% to 58%, in America is 27% (14-38), in Europe is 38% (33-42), Eastern Mediterranean is 61% (55-67), South Eastern Asia is 59% (40-78), Western Pacific is 55% (51-59), while its prevalence in Africa is 91% (87-94) [8].

This review showed a high tetracycline resistance and poor inhibitory effect on *H. pylori* with 100% resistance in 33.3% of the studies that evaluated tetracycline resistance with a mean tetracycline resistance of 56.0%. Amoxicillin is extensively used in Nigeria for self-medication to treat 'typhoid fever' as many illnesses with fever are misdiagnosed as malaria or typhoid fever by non-medically qualified

persons. Amoxicillin is sold on the streets of Nigeria by drug hawkers. This is also compounded by increased ampicillin use, which could lead to cross-resistance of *H. pylori* to ampicillin.

There is a high susceptibility of *H. pylori* to ciprofloxacin. Four out of the seven studies that evaluated ciprofloxacin showed 100% susceptibility. This is similar to the findings in some other parts of Africa [26-29]. This finding suggests that ciprofloxacin could be a credible therapeutic addition in treating *H. pylori* infection in Nigeria. Quinolones exert antimicrobial activity on *H. pylori* by inhibition of DNA gyrase [30].

Rifabutin, or furazolidone-based rescue therapy, is an encouraging treatment strategy in the presence of preceding multiple eradication failures. The major side effect of rifabutin is myelotoxicity. Furazolidone, a monoamine oxidase inhibitor, has demonstrated high antibiotic activity against *H. pylori*. Currently, primary resistance to furazolidone by *H. pylori* is rare. No studies have yet evaluated rifabutin and furazolidone efficacy in Nigeria [31].

Treatment failure has also been documented in some patients due to poor socio-economic status and out-of-pocket payment system barring their return to the clinic to access their medications, leading to high rate of failure to complete their course of treatment. Where available, endoscopic biopsy and culture with antibiotic sensitivity testing are the most suitable options for patients with two eradication therapy failures. The subsequent treatment should avoid metronidazole, clarithromycin, and other antibiotics that may have contributed to the development of resistance [28]. As a general rule, patients who recorded *H. pylori* eradication failure with clarithromycin combination therapy should not be re-treated with clarithromycin as mutational patterns (A2143G, A2142G, and A2142C) that confer clarithromycin resistance cannot be overcome by increasing the dosage, increasing the duration of treatment or shortening the dosing interval.

Suggestion

There were only four studies that evaluated antibiotic resistance in Nigeria. Triple therapy was the regimen in all, and eradication rates were variable. There were no studies yet on sequential or quadruple therapy. The paucity of studies on *H. pylori* eradication is a significant limitation of *H. pylori* management in Nigeria. More studies are needed in Nigeria to evaluate *H. pylori* eradication rates conclusively.

H. pylori eradication rates in Nigeria remain relatively reasonable though suboptimal to the globally accepted minimum eradication rates of 90%. There is a need for an alternative efficacious triple therapy as a first-line combination regimen that would meet the global target. Rifabutin combination therapy would be a credible alternative in Nigeria, given its efficacy in other countries that use it for *H. pylori* eradication. Studies should be carried out on different treatment regimens, such as sequential and quadruple therapy (bismuth or non-bismuth).

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