BMJ Open Quality

Improving routine prenatal penicillin allergy testing for reported penicillin allergy

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To cite: Gill MM, Gasner S, Banken A, *et al*. Improving routine prenatal penicillin allergy testing for reported penicillin allergy. *BMJ Open Quality* 2022;**11**:e001859. doi:10.1136/bmjoq-2022-001859

Received 14 February 2022
Accepted 28 June 2022

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ABSTRACT

Background Patients with self-reported antibiotic allergies have a higher cost of care, more frequent infections with resistant bacteria and worse health outcomes than patients without antibiotic allergies. Ultimately, less than 5% of patients who report a penicillin allergy have a clinically significant immune-mediated hypersensitivity reaction when tested. As 10%–30% of the population of pregnant patients are colonised for group B *Streptococcus* (GBS) and guidelines recommend penicillin as the treatment of choice for GBS, current recommendations support penicillin allergy testing in pregnant patients who report an allergy.

Methods and intervention In this quality improvement project, nursing staff used an algorithm outlining inclusion and exclusion criteria to determine which patients were eligible to have penicillin allergy testing completed. Penicillin allergy testing consisted of a skin test using benzylpenicilloyl polylysine (Pre-Pen), penicillin G potassium, amoxicillin and alkaline hydrolysis mix (penicilloate) as a prick skin test, followed by intradermal skin test and finally an oral challenge with either amoxicillin or penicillin. Patient outcomes were analysed to evaluate the impact of the intervention.

Results Of the 1266 patients receiving prenatal care during the intervention, 236 (19%) reported a history of penicillin allergy, and 212 if these were eligible for testing. 150 of the eligible patients were offered penicillin allergy testing. 101 patients (67%) completed testing and 49 (33%) declined testing. Seven patients (7%) had positive penicillin allergy testing, while 94 patients (93%) had negative penicillin allergy testing and were immediately de-labelled as penicillin allergic. Seventeen of the de-labelled patients subsequently tested positive for GBS colonisation, and all received intrapartum penicillin without adverse events.

Conclusions Pursuing penicillin allergy testing for pregnant patients with reported penicillin allergy is a safe and feasible approach, allowing for allergy de-labelling and safe, guideline-driven antimicrobial therapy during subsequent labour and delivery hospitalisations. Cost-effectiveness of the allergy testing and impact on later episodes of care should be further investigated.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Our findings align with the conclusion of other papers: penicillin skin testing can be safely performed in pregnancy.

WHAT THIS STUDY ADDS

⇒ This publication details testing results and pregnancy outcomes for a large cohort of pregnant patients with a reported penicillin allergy.

⇒ This publication outlines suggestions for a successful de-labelling implementation strategy.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ By successfully de-labelling pregnant patients, providers will be able to safely follow guideline-driven antimicrobial therapy and use first-line antibiotics in labour and delivery for group B Streptococcus-positive patients.

INTRODUCTION

Adverse reactions to medications are commonly reported by patients and are usually noted as an allergy in the medical record. Penicillin is the most common antibiotic allergy reported by patients receiving healthcare in the USA,[1] with approximately 10% of non-hospitalised patients reporting this to healthcare providers.[1 2] In hospitalised patients, penicillin allergy is also the most commonly reported antibiotic allergy, occurring in 10%–25% of patients.[1 3–5] In one study of a large cohort of patients, only 20% of patients with a documented allergy had the adverse reaction to the antibiotic characterised.[6] When reported adverse reactions to antibiotics are not explored by prescribing providers, it often results in the use of alternative broad-spectrum treatment than is required for the clinical scenario. This practice contributes to the overuse of broad-spectrum agents which has added to the emergence of multiple drug-resistant microbes, which directly undermines the urgent goals of antimicrobial stewardship. Interestingly, for patients with a history of antibiotic-associated anaphylaxis, only 20%–50% will have a positive skin test when tested within 3 months of the reported anaphylaxis.[7] Ultimately, <5% of patients

who report a penicillin allergy have a clinically significant IgE-mediated or T lymphocyte-mediated hypersensitivity when tested.[2]

Group B *Streptococcus* (GBS) is the most common infectious cause of morbidity and mortality in neonates.[8] The primary risk factor for early onset GBS infection in neonates is colonisation of the maternal rectum or genital tract. Between 10% and 30% of pregnant patients are colonised.[9 10] Because of the significant morbidity and mortality associated with this condition, both the Centers for Disease Control and The American College of Obstetrics and Gynecology (ACOG) recommend universal culture-based screening of the vagina and rectum for all prenatal patients in each pregnancy unless they are previously identified as being colonised based on the presence of GBS bacteriuria.[11] Intrapartum administration of antibiotics interrupts vertical transmission of GBS from colonised mothers to their infants, decreasing the incidence of invasive GBS infections in the neonate.[12–15] GBS remains susceptible to both penicillin G and ampicillin. Due to the narrower spectrum of antimicrobial coverage, penicillin G remains the treatment of choice for GBS infections.[8]

Patients who report a history of a penicillin allergy should have susceptibility testing performed if the GBS culture is positive. GBS-positive, penicillin allergic patients with a history of minor drug reactions can be treated with cefazolin, which readily crosses the placenta and can be detected in cord blood and amniotic fluid at levels that are above the GBS minimal inhibitory concentration.[8] If maternal indications preclude the use of beta-lactam antibiotics, then use of clindamycin or vancomycin may provide protection against newborn infection if supported by antimicrobial susceptibility testing. Susceptibility testing and the use of broad-spectrum antibiotics add to the cost of care and the potential for development of antibiotic resistance.

ACOG published a practice bulletin in 2020 recommending that all pregnant patients who report a penicillin allergy be tested to identify those with a true penicillin allergy.[11] This is in alignment with the American Academy of Allergy, Asthma and Immunology's 2016 recommendation that penicillin allergy testing should be routinely performed on all patients with a listed allergy to penicillin, ampicillin or amoxicillin.[16] Since patients with a penicillin allergy have a 50% increased likelihood of a surgical site infection as reported by Blumenthal *et al*,[17] allergy testing has considerable downstream implications for our pregnant patients undergoing caesarean delivery as well.

Protocols for penicillin allergy testing are well established. For patients with a negative skin test to penicillin reagents, followed by an oral challenge that is tolerated without adverse event, penicillins can be used without an increased risk of IgE-mediated allergic reaction.[16] The negative predictive value of this method of testing exceeds 98%.[2 16 18] Penicillin allergy testing has been studied and documented to be safe for pregnant patients.[19–21]

With the goal of improving antimicrobial stewardship for our prenatal patients, we undertook a quality improvement project to identify patients with a self-reported penicillin allergy who could be treated with this first-line antibiotic in labour. We report real-world results from this project implementation.

METHODS AND INTERVENTION

This is a quality improvement project including pregnant patients receiving prenatal care between 1 March 2020 and 1 March 2021 at Mayo Clinic Rochester who reported a penicillin or amoxicillin allergy. Patients receiving prenatal care during this time frame who did not report a penicillin allergy were used as a control group for this quality improvement project.

We established a standardised protocol wherein nursing staff reviewed and updated the allergy section of the medical record for pregnant patients on entry to prenatal care. For each medication allergy, patients were asked to confirm or describe the type of allergic reaction experienced. Using an algorithm outlining inclusion and exclusion criteria (figure 1), nursing staff then determined which patients were eligible to have penicillin allergy testing completed. All eligible patients were offered penicillin allergy testing by phone during the initial obstetrics nurse visit or by a portal message if they had already been seen to establish care prior to the start of this project. Penicillin allergy testing was ordered using a nursing protocol and educational information was given to patients (figure 1).

Penicillin allergy testing consisted of a skin test using benzylpenicilloyl polylysine (Pre-Pen), penicillin G potassium, amoxicillin and alkaline hydrolysis mix (penicilloate), as previously reported.[22] Penicillin skin test was performed on the volar surface of the patient's forearm. Prick skin test was followed by intradermal skin test, as previously reported.[22] We used the skin test parameters including the definition of a positive penicillin skin test as outlined in AAAI practice parameter[23] and by others.[24 25] A positive test was defined as a weal of 3×3 mm or greater with erythema above the negative control. While there is no uniform agreement on what constitutes a positive skin test response, most experts agree that it is defined by the size of the weal, which should be 3 mm or greater than that of the negative control for either prick, puncture or intradermal tests.

Following a negative penicillin skin test, patients were offered an oral challenge to either amoxicillin or penicillin V Potassium at the discretion of the consulting allergist. While there is good evidence for the safety of a single or two-dose challenge, as a practice we performed a three-dose challenge protocol in an abundance of caution for the safety of our pregnant patients.[26] In our challenge, patients were given 1:100 of target dose followed by 1:10 and 1:1 with a 60 min observation period between each dose and final dose. The target dose for amoxicillin was 500 mg compared with 250 mg for penicillin VK for

Inclusion Criteria

- Pregnancy
- History* of non-life-threatening reaction to penicillin, ampicillin, dicloxacillin, or amoxicillin (*Examples* include cough, hives, rash, localized swelling, diarrhea, nausea, or vomiting)

Exclusion Criteria

History* of any of the following:

- Severe allergic reaction to penicillin antibiotic, including anaphylaxis, angioedema, respiratory distress, shortness of breath, difficulty swallowing, or swelling of throat, lips, tongue, or periorbital skin
- Stevens-Johnson Syndrome
- Penicillin antibiotic reaction including nephritis, hepatitis, hemolysis, or posterior reversible encephalopathy syndrome
- Skin testing confirming allergy to penicillin, ampicillin, dicloxacillin, or amoxicillin.

Plan of care for eligible patients

- Order penicillin allergy consultation with penicillin skin test.
- Inform the patient that penicillin is an effective and safe treatment for GBS colonization in pregnant women. If allergy testing is negative, the cost of sensitivity testing on a positive GBS culture and the added cost of broad-spectrum antibiotics can be avoided.
- Document the patient's level of understanding and agreement to testing.
- Inform the patient that test results will be sent to the ordering provider and discussed with her at her next visit.
- Advise patients taking an H2 blocker (cimetidine, famotidine, nizatidine, ranitidinde) or an anti-histamine (cetirizine, diphenhydramine, fexofenadine, loratadine) to stop taking the medication for at least three days prior to allergy testing.

Figure 1 Structured intervention using a nursing protocol for testing implementation. GBS, group B *Streptococcus*. *Patient self report or medical record documentation.

patients >30 kg. A successful oral challenge was defined as no adverse reaction to the oral challenge consistent with an immediate hypersensitivity reaction. The patients were dismissed after a successful oral challenge to amoxicillin or penicillin VK.

RESULTS

Of the 1266 patients receiving prenatal care during the defined time range, 236 (19%) reported a history of penicillin allergy (figure 2). Sixty-two patients with a documented beta-lactam allergy were not offered testing, either because the timing (eg, presented in labour), because the location of their initial care resulted in bypassing of the nursing protocol (n=47) or because they experienced early pregnancy loss (n=15). Twenty-four of the patients reporting a penicillin allergy (10%) were deemed to have a valid allergy based on our inclusion criteria and were not offered testing. Of the 150 patients offered allergy testing, 49 (33%) declined testing, resulting in penicillin allergy testing being completed in 101 (67%) patients who were identified to be eligible. Seven of these patients (7%) had a positive penicillin allergy test. Ninety-four patients (93%) had a both a negative penicillin allergy test and a negative oral challenge and were subsequently

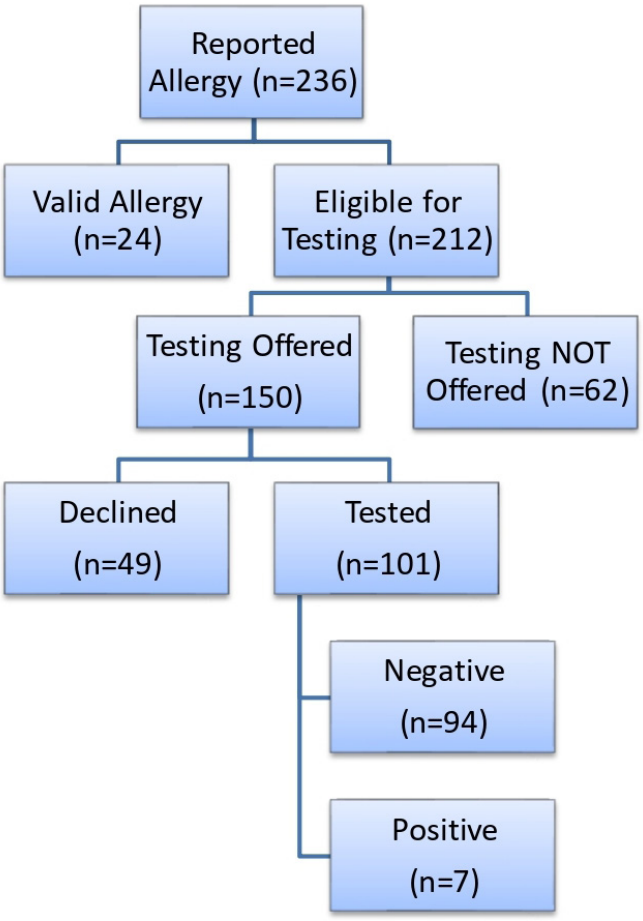

Figure 2 Outcomes for patients reporting penicillin allergy.

immediately de-labelled as penicillin allergic. None of the patients who received an oral challenge experienced subjective symptoms or an allergic response after the challenge, and none contacted the division of allergy, their primary obstetric provider or the emergency room to report a delayed challenge reaction.

The demographics and clinical characteristics of the 1266 patients according to penicillin allergy status at the time of their initial prenatal visit and whether allergy testing was performed are presented in table 1 for the 1030 patients without a self-reported penicillin allergy, 125 patients with a self-reported penicillin allergy and allergy testing or a documented valid allergy and 111 patients with a self-reported penicillin allergy and no allergy testing. There were statistically significant differences between at least two of the three subgroups for gravidity, alcohol use, education level, GBS testing, delivery route and gestational age. In particular, patients with a self-reported penicillin allergy who either underwent allergy testing or had a documented valid allergy were more likely to report alcohol use prior to pregnancy (45.9% (56/122) vs 29.9% (295/988), p<0.001), have a bachelor's degree or higher education (72.1% (88/122) vs 59.6% (570/956), p=0.008) and have GBS testing done (92.8% (116/125) vs 78.1% (804/1030), p<0.001) compared with patients without a self-reported penicillin allergy. Furthermore, this subgroup was also more likely to have GBS testing done (92.8% (116/125) vs 75.7% (84/111), p<0.001) compared with the subgroup with a self-reported penicillin allergy who did not undergo allergy testing. The subgroup with a self-reported penicillin allergy who did not undergo testing was more likely than the other two subgroups to have a gravida or two or more (82.9% (92/111) vs 69.4% (715/1030) and 63.2% (79/125), p=0.003 and p<0.001, respectively) and a lower median gestational age (median, 39.0 vs 39.1 and 39.3, p=0.009 and p=0.008, respectively). In addition, this subgroup was more likely than those without a self-reported penicillin allergy to have a caesarean delivery (42.2% (38/90) vs 28.5% (230/806), p=0.007, among those who delivered at an affiliated institution). Other demographic variables, including parity, maternal age, prepregnancy body mass index (BMI), tobacco or drug use and marital status along with birth weight at delivery, were not significantly different between the three subgroups.

Comparing the cohort of patients who tested negative for penicillin allergy with those who tested positive or had a valid allergy, there were no significant differences in age, BMI, marital status and alcohol or tobacco use (table 2). Patients with a valid allergy or positive penicillin allergy testing had higher median gravidity compared with those with negative penicillin allergy testing (3 vs 2 pregnancies, p=0.01), and were also more likely to report illicit drug use (12.9% (4/31) vs 1.1% (1/91), p=0.004). Interestingly, the type of beta-lactam allergy among those who tested positive or had a valid allergy included 45.2% with an allergy to penicillin only, 38.7% with an allergy to amoxicillin or ampicillin only and 16.1% with an allergy to both, whereas the majority (74.5%,70/94) of the patients who tested negative reported an allergy to amoxicillin or ampicillin only.

Of the 31 patients who either had a positive penicillin allergy testing (n=7) or were not tested because they met our criteria for valid allergy (n=24), 4 (12.9%) were GBS positive and required alternatives to penicillin and amoxicillin in labour. In the subgroup of 94 patients that had negative penicillin allergy testing, 17 (18.1%) were GBS positive and allergy de-labelling resulted in use of penicillin in labour in all 17 patients. None of these de-labelled patients experienced an allergic reaction to penicillin during or after labour, and eight also received cefazolin for surgical prophylaxis without adverse effects.

DISCUSSION

Patient-reported antibiotic allergies directly impact patient care by limiting options for antibiotic selection. Patients with self-reported antibiotic allergies have a higher cost of care, more frequent infections with resistant bacteria and worse health outcomes than patients without antibiotic allergies.[2 17 22] Given that penicillin allergies are the most commonly reported antibiotic allergy, pursuing penicillin

Table 1 Comparisons according to penicillin allergy status at initial prenatal visit and whether allergy testing was performed

Characteristic	Penicillin allergy reported at prenatal visit			
	No (n=1030)	Yes and either a documented valid allergy or tested (n=125)†	Yes and not tested (n=111)†	P value*
Gravidity during pregnancy, median (IQR)	2 (1, 3)	2 (1, 3)	2 (2, 4)	0.014
Parity during pregnancy, median (IQR)	1 (0, 2)	1 (0, 2)	1 (0, 2)	0.17
Age (years), mean (SD)	30.2 (5.1)	30.4 (4.2)	30.7 (4.9)	0.67
Prepregnancy BMI (kg/m^2)	N=763	N=114	N=81	0.46
Median (IQR)	25.1 (21.8, 30.1)	24.4 (22.2, 28.9)	24.7 (22.8, 32.1)	
Alcohol use				0.006
Yes	295 (28.6%)	56 (44.8%)	37 (33.3%)	
No	693 (67.3%)	66 (52.8%)	71 (64.0%)	
Not documented	42 (4.1%)	3 (2.4%)	3 (2.7%)	
Tobacco use				0.64
Yes	89 (8.6%)	9 (7.2%)	11 (9.9%)	
No	929 (90.2%)	116 (92.8%)	98 (88.3%)	
Not documented	12 (1.2%)	0 (0.0%)	2 (1.8%)	
Illicit drug use				0.82
Yes	45 (4.4%)	5 (4.0%)	6 (5.4%)	
No	943 (91.6%)	117 (93.6%)	102 (91.9%)	
Not documented	42 (4.1%)	3 (2.4%)	3 (2.7%)	
Marital status				0.09
Married or life partnership	791 (76.8%)	106 (84.8%)	82 (73.9%)	
Single, divorced, separated or widowed	239 (23.2%)	19 (15.2%)	29 (26.1%)	
Education level				0.002
High school degree or less education	163 (15.8%)	6 (4.8%)	16 (14.4%)	
Associate degree or some college	223 (21.7%)	28 (22.4%)	26 (23.4%)	
Bachelor's degree or more	570 (55.3%)	88 (70.4%)	66 (59.5%)	
Not documented	74 (7.2%)	3 (2.4%)	3 (2.7%)	
Group B *Streptococcus* testing				0.002
Positive	178 (17.3%)	21 (16.8%)	20 (18.0%)	
Negative	626 (60.8%)	95 (76.0%)	64 (57.7%)	
Not documented or not done	226 (21.9%)	9 (7.2%)	27 (24.3%)	
Pregnancy outcomes, among those who delivered at an affiliated institution	N=806	N=119	N=90	
Delivery route				0.026
Caesarean delivery	230 (28.5%)	37 (31.1%)	38 (42.2%)	
Vaginal	576 (71.5%)	82 (68.9%)	52 (57.8%)	
Gestational age (weeks), median (IQR)	39.1 (38.4, 40)	39.3 (38.4, 40.0)	39.0 (37.6, 39.4)	0.019
Birth weight (g), median (IQR)	3395 (3050, 3742)	3480 (3170, 3720)	3375 (2900, 3680)	0.18

IQR=25th and 75th percentiles.
*Comparisons between the groups were evaluated using an F-test from a one-way analysis of variance model for age, the non-parametric Kruskal-Wallis test for all other continuous or count variables and the χ^2 test for all other variables. A p value <0.05 indicates that at least two of the three subgroups are significantly different from each other. For patient characteristics with an overall p value <0.05, additional pairwise comparisons were performed between the subgroups and the significant results of these comparisons are reported in the 'Results' section.
†Among the 236 patients with a penicillin allergy reported at a prenatal visit, 125 had either a documented valid penicillin allergy (n=24) or were tested during the current pregnancy (n=101). The remaining 111 were not tested because either testing was not offered (n=62) or the patient refused (n=49).
BMI, body mass index.

Table 2 Comparisons among those with reported allergy, according to penicillin allergy testing result

Characteristic	Tested negative (n=94)	Valid allergy or tested positive (n=31)	P value*
Gravidity during pregnancy, median (IQR)	2 (1, 3)	3 (1, 5)	0.01
Parity during pregnancy, median (IQR)	1 (0, 1)	1 (0, 2)	0.11
Age (years), mean (SD)	30.2 (4.0)	30.9 (4.7)	0.40
Prepregnancy BMI (kg/m^2), median (IQR)	24.6 (22.2, 29.4)	24.2 (22.2, 27.2)	0.39
Alcohol use			0.53
Yes	43 (45.7%)	13 (41.9%)	
No	48 (51.1%)	18 (58.1%)	
Not documented	3 (3.2%)	0 (0.0%)	
Tobacco use			0.16
Yes	5 (5.3%)	4 (12.9%)	
No	89 (94.7%)	27 (87.1%)	
Illicit drug use			0.009
Yes	1 (1.1%)	4 (12.9%)	
No	90 (95.7%)	27 (87.1%)	
Not documented	3 (3.2%)	0 (0.0%)	
Marital status			0.46
Married or life partnership	81 (86.2%)	25 (80.6%)	
Single, divorced, separated or widowed	13 (13.8%)	6 (19.4%)	
Education level			0.02†
High school degree or less education	4 (4.3%)	2 (6.5%)	
Associate degree or some college	20 (21.3%)	8 (25.8%)	
Bachelor's degree or more	70 (74.5%)	18 (58.1%)	
Not documented	0 (0.0%)	3 (9.7%)	
Reported allergy			
Penicillin and/or amoxicillin/ampicillin allergy			0.001
Penicillin only	18 (19.1%)	14 (45.2%)	
Amoxicillin/Ampicillin only	70 (74.5%)	12 (38.7%)	
Both penicillin and amoxicillin/ampicillin	6 (6.4%)	5 (16.1%)	
Multiple beta-lactam allergies			0.06
Yes (at least two of penicillin, amoxicillin/ampicillin, or cephalosporin)	11 (11.7%)	8 (25.8%)	
No	83 (88.3%)	23 (74.2%)	
Group B *Streptococcus* testing			0.69
Positive	17 (18.1%)	4 (12.9%)	
Negative	71 (75.5%)	24 (77.4%)	
Not documented or not done	6 (6.4%)	3 (9.7%)	
Pregnancy outcome			--
Delivered at affiliated institution	90 (95.7%)	29 (93.5%)	
Delivered elsewhere	2 (2.2%)	0 (0.0%)	
Early pregnancy loss	1 (1.1%)	1 (3.2%)	
Lost to follow-up	1 (1.1%)	1 (3.2%)	
Delivery route‡			0.36
Caesarean section	26 (28.9%)	11 (37.9%)	
Vaginal	64 (71.1%)	18 (62.1%)	

Continued

Table 2 Continued

Characteristic	Tested negative (n=94)	Valid allergy or tested positive (n=31)	P value*
Gestational age (weeks), median (IQR)‡	39.3 (38.4, 40.1)	39.3 (38.4, 39.7)	0.49
Birth weight (g), median (IQR)‡	3500 (3200, 3720)	3410 (3170, 3680)	0.57

IQR=25th and 75th percentiles.
*Comparisons between the groups were evaluated using the two-sample t-test for age, the Wilcoxon rank sum test for all other continuous or count variables and the χ^2 test for all other variables.
†When the categories were further collapsed to compare those with versus without a bachelor's degree or more (74.5% (70/94) vs 64.3% (18/28)), the difference did not attain statistical significance (p=0.29).
‡Restricted to those who delivered at the affiliated institution.
BMI, body mass index.

allergy testing for pregnant patients with a self-identified penicillin allergy directly impacts pregnancy care because of routine testing for GBS colonisation. Because patients who were colonised with GBS in one pregnancy have a 50% likelihood of colonisation in subsequent pregnancies,[27] the benefits of pursuing penicillin allergy testing during pregnancy extend beyond a single episode of care. The negative predictive value of a penicillin allergy test is reported to be 98%,[28] making the risk of a reaction in test-negative patients about the same as in the general population. While the positive predictive value is only about 50%,[18] it is appropriate to seek alternatives to penicillin for those with positive penicillin allergy testing.

Recent publications on this topic include retrospective reviews of pregnant patients receiving penicillin skin testing followed by an oral challenge to confirm tolerance of penicillin,[20 29] and a systematic literature review positing that desensitisation should be used more frequently in the pregnant population to mitigate the sequelae of unverified penicillin allergies.[30] Our findings align with the conclusions of other papers: penicillin skin testing can be safely performed in pregnancy and a negative test allows providers to safely follow guideline-driven antimicrobial therapy and use first-line antibiotics in labour and delivery for GBS-positive patients.[20 29 31] In addition, our publication provides a structured way to approach this evaluation in pregnant patients.

We recognise there are limitations of our project relating to both patient acceptance of penicillin allergy testing recommendations and some systematic inconsistency in implementation of the nursing protocol for those who did not initiate their prenatal care within our practice. During the project time, we made serial overtures to providers and nurses to overcome barriers to implementation. Several influencing factors were identified in the population eligible for penicillin allergy testing but who ultimately declined testing. Some patients expressed concern about the cost of testing, and providers were not able to persuade them that a negative test might represent long-term healthcare cost savings and reduce their future risk of developing infections that are resistant to broad-spectrum antibiotics. A group of patients cared for remotely early during the COVID-19 pandemic were reluctant to come to the office for allergy testing. Thus, both timing of the project during the pandemic and the cost of the intervention limited uptake in this population.

Because most pregnant patients have decades of future life expectancy, the value of penicillin allergy testing and de-labelling during pregnancy may manifest across many years. The American College of Obstetrics and Gynecology recommends routine performance of penicillin allergy testing for patients with a history of penicillin allergy, in part to promote antibiotic stewardship and also to encourage adherence to guideline-directed optimal antibiotic therapy for GBS prophylaxis in pregnancy.[11] In our patient population, 93% (94/101) of patients who completed penicillin allergy testing were subsequently de-labelled as allergic. Among these 94 patients, the subset of 17 who tested positive for GBS were able to be treated with penicillin in accordance with current guidelines. Our results support the feasibility, effectiveness and safety of routine penicillin allergy testing in pregnancy. Further research is needed to examine cost-effectiveness of this approach, the impact of testing over the lifetime of the patient and to identify strategies to maximise uptake of testing among eligible populations.

Contributors The quality improvement project was authored by MMG with RT's collaboration. AB and SG helped write the nursing protocol and oversaw implementation of it in the outpatient clinic. MP supervised allergy testing of pregnant patients. ES reviewed retrospectively the delivery records of allergy de-labelled patients. AW performed statistical analysis for all patients. All authors contributed to this manuscript with MMG serving as primary author. MMG is guarantor.

Funding This work was supported by the Advance the Practice Research Award from the Mayo Clinic Office of Translation to Practice.

Disclaimer The content is solely the responsibility of the authors and does not necessarily represent the official views of Mayo Clinic.

Competing interests RT has research funding and know-how agreements with HeraMed, unrelated to this project.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Because this was a quality intervention, it was deemed to be non-research by the Mayo Clinic institutional review board. All listed authors have met the ICMJE requirements for authorship. This work has not been previously publicly reported elsewhere.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data sharing not applicable as no datasets generated and/or analysed for this study. All data relevant to the study are included in the article or uploaded as supplementary information. All data are included in the publication.

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