



The acceptability and feasibility of implementing a Fractional exhaled Nitric Oxide (FeNO)-based asthma management strategy into antenatal care: The perspective of pregnant women with asthma

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Introduction

The prevalence of asthma in pregnancy has increased in the US from 5.5% in 2001 to 7.8% in 2007 (Hansen et al., 2013) with the most recently reported prevalence in 2019 of 9.1% (Cohen et al., 2019). Sweden has a prevalence of 9.4% (Reino et al., 2014). In Australia, asthma is the most common chronic condition during pregnancy, complicating 12.7% of pregnancies (Sawicki et al., 2012). The increased risk of adverse maternal (gestational diabetes [RR 1.39, 95% CI 1.17, 1.66]; hypertension and pre-eclampsia [RR 1.54, 95% CI 1.32–1.81]) and fetal outcomes (low birth weight [RR 1.46, 95% CI 1.22–1.75]; premature birth [RR 1.41, 95% CI 1.22–1.61]) with maternal asthma is well documented (Murphy et al., 2011; Namazy et al., 2012; Murphy et al., 2013; Wang et al., 2014). Adverse outcomes are further increased if the woman experiences exacerbation of her asthma symptoms during pregnancy (Namazy et al., 2013; Wang et al., 2014). Thus, optimising asthma control and minimising exacerbations is the goal of antenatal asthma management.

Currently asthma is predominately managed using inhaled corticosteroids (ICS), with or without long-acting β -agonist (LABA)

as a preventer medication, together with a short-acting β -agonist (SABA) as a reliever medication. Oral corticosteroids (OCS) may also be prescribed to treat asthma exacerbations. Continuing asthma medications during pregnancy is considered safer than the risk of an asthma exacerbation (National Heart, Lung, and Blood Institute, 2005; National Asthma Council, 2016). Despite there being evidence of safety and effectiveness of pharmacological antenatal asthma management, some women and their health practitioners continue to express concern as to the optimal dosing and safety of asthma medications during pregnancy (Lim, Stewart et al., 2011). This in turn can lead to under-use of asthma medications and medication non-adherence during pregnancy (Lim et al., 2012; Robijn, 2018).

A novel way of managing asthma in pregnancy is using the measurement of Fractional exhaled Nitric Oxide (FeNO) to help determine the dosage of ICS required to reduce lung inflammation. This way of managing asthma in pregnancy has been shown to effectively reduce exacerbations whilst minimising medication exposure in adults with asthma (Tsiligianni et al., 2017). FeNO is a valid biomarker of T helper Type-2 (T2) eosinophilic airway inflammation (Syk et al., 2009). This measurement is collected via a simple breathing test and the measurement can be used to titrate ICS dosage for people with asthma. The use of this biomarker to guide pharmacological antenatal asthma management significantly reduced exacerbations in pregnant women with asthma in the double-blind, parallel-group Managing Asthma in Pregnancy (MAP) randomised controlled trial (RCT) (Powell et al., 2011).

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Table 1
BLT interventions based on randomisation.

FeNO-based management group	Control group
<ul style="list-style-type: none"> • Regular (every 4–6 weeks) review of their asthma by a research nurse or midwife. Including measurement of their FeNO level via a simple breathing test and assessment of their asthma symptoms via the Asthma Control Questionnaire (ACQ). • Self-management education provided, inhaler technique checked and smoking status confirmed via measurement of exhaled carbon monoxide. • This information along with current medication use and smoking status was entered via an iPad, into an algorithm developed for the BLT study. • The electronic algorithm determines the need for changes in asthma medication for the pregnant woman with asthma • Asthma medication were provided free of charge to the pregnant women as required 	<ul style="list-style-type: none"> • One visit with the research nurse/midwife where general asthma status was determined via spirometry. • Self-management education provided, inhaler technique checked and smoking status confirmed via measurement of exhaled carbon monoxide. • Nil medications were provided and women were encouraged to continue asthma management with their GP during their pregnancy.

Specifically, 220 non-smoking pregnant women with asthma, were recruited and randomised prior to 22 weeks gestation. Exacerbations were significantly reduced by 50% in the FeNO group compared to the control group (0.288 vs 0.615 exacerbations per pregnancy; incidence rate ratio 0.496, 95% CI 0.325–0.755; $p = 0.001$)(Powell et al., 2011). A significant reduction in the dose of ICS, OCS and SABA use, whilst maintaining asthma control, was also observed in the FeNO-based management group vs. controls. Therefore, FeNO-guided asthma management may facilitate good asthma control whilst minimising medication exposure during pregnancy, an ideal situation for both pregnant women and their health professionals.

FeNO-based antenatal asthma management may also benefit the future health of offspring, with follow-up studies of infants born to women in the MAP cohort reporting those born to mothers in the FeNO group were less likely to have recurrent bronchiolitis, croup or asthma than those in the control group (Mattes et al., 2014; Morten et al., 2017).

Following on from the MAP study, the Breathing For Life trial (BLT) (Murphy et al., 2016) is testing whether FeNO-based antenatal asthma management, compared to 'usual' care, reduces the incidence of adverse perinatal outcomes in babies born to women with asthma. One of the aims of the BLT was to also assess the acceptability and feasibility of implementing FeNO in clinical practice. This multicenter, unblinded, parallel-group RCT has randomised 1200 smoking and non-smoking pregnant women with asthma, with an expected completion date in early 2020. A description of the intervention and control arms of the BLT RCT are shown in Table 1. After being randomized, the control group women received usual care from their primary health care provider. This qualitative study was conducted and analysed prior to completion of the main trial, and hence the findings of the main trial are as yet unknown.

Whilst the effectiveness of FeNO-based antenatal asthma management continues to be studied, the process of implementing this novel approach into clinical practice needs to be examined. The acceptability of healthcare interventions is a key consideration in their design, evaluation and implementation (Sekhon et al., 2017). Acceptability is a multi-faceted concept and reflects whether the intervention is considered to be appropriate to those delivering or receiving it (Sekhon et al., 2017). Pregnant women with asthma are key stakeholders and therefore are ideal to consider the perceived feasibility of implementing FeNO-based management into regular antenatal care. It is therefore important to examine the anticipated or experienced emotional and cognitive responses to the

FeNO-based management strategy from the perspective of pregnant women with asthma.

Aim

This study aimed to assess whether pregnant women with asthma considered the introduction of a FeNO-based asthma management strategy into antenatal care as acceptable, defined as, *the perception among stakeholders that an intervention is agreeable* (Peters et al., 2013) and feasible, the extent to which an intervention can be carried out in a particular setting or organization (Peters et al., 2013).

Method

A qualitative descriptive study design, including video elicitation, was used to allow pregnant women to openly express their opinions and to allow the emergence of new information. In line with Sandelowski's assertion, the intention in this qualitative descriptive study is not to generate theory or propose conceptual linkages between the themes but to accurately reflect participants perspectives in plain language (Sandelowski, 2000). Ethical approval to conduct the study was granted by the Human Research Ethics Committees of the Hunter New England Local Health District (16/09/21/4.01) and the University of Newcastle (h-2019-0010).

Prior to completion of the BLT study, pregnant women with asthma, in their third trimester, currently enrolled in BLT formed a purposive sample and were recruited from two of the BLT sites, the John Hunter Hospital (JHH), Newcastle, and the Royal Hospital for Women (RHW), Randwick. These tertiary referral hospitals are in metropolitan regions of New South Wales, Australia. Both hospitals are within the public health system and accommodate approximately 4000 births per annum. The antenatal clinics see approximately 50 women per day in various models of care including midwifery, obstetric and General Practitioner (GP) shared care.

Pregnant women with asthma currently randomised to either the FeNO or control group of BLT were given information about the study by the BLT research nurse or midwife when she attended their research visits. Women from both arms of the trial were invited to participate in order to widen the potential pool of participants and with no comparative approach in mind. If the woman consented to be interviewed, her contact details were provided to the midwife/researcher (KM), who arranged a date, time and place to conduct an interview with the woman. Following written informed consent, face-to-face interviews were conducted by KM.

All participants chose to be interviewed in the clinic setting. Interviews focused on the pregnant woman's asthma management prior to and during the current pregnancy. A video (Appendix A) demonstrating the FeNO-based intervention being trialed during a BLT research visit was viewed during each interview. This ensured consistency of information provided about the process and stimulated thoughts about the use of FeNO in clinical practice. This video was particularly aimed at the women in the control arm of BLT who had not experience FeNO as part of their usual care. In order to guide discussion about asthma management, including the use of FeNO, an interview schedule (Appendix B) was followed. All interviews were digitally recorded and transcribed verbatim. Data analysis was a continuous process from the first interview with identification of key words and discussion with the research team which continued until data saturation was reached (Fusch 2015). Data saturation in this study meant that no new insights were provided by participants following the 10th interview from the intervention group and the 6th interview from the control group. One further interview was undertaken in each group to confirm this. All data were initially analysed as one set and subsequently analysed separately in BLT intervention and control groups to see if there were similarities or differences in their responses.

The four-stage process described by Morse and Fields (1996) was used during the content analysis of these data. Data immersion and reflection on field notes allowed for data comprehension during analysis. Preliminary themes and sub-themes generated from the transcripts were discussed amongst the research team until consensus was reached. Documenting an audit trail, the use of a well-established research method, providing a thorough description of the study setting to aid in transferability, using participant quotes to illustrate the origin of the findings and peer review of the analysis were all completed to ensure rigour. All participants received a copy of their interview transcript and were given the opportunity to comment on or make amendment to the data prior to its inclusion in the data set, ensuring member checking occurred (Miles et al., 2014).

Results

Interviews were conducted with 18 pregnant women from June 2018 – February 2019; 11 women randomised to the FeNO-management group of BLT (identified as participant 'PF') and seven from the control group (identified as participant 'PC'). The average length of the interviews was 23 min. Most women described being first diagnosed with asthma as a child and the majority relied on their GP to manage their asthma. The gestational age of women ranged from 32 to 38 weeks with the average being 34.5 weeks gestation at the time of the interview (Table 2).

Two themes and eight sub-themes were identified during thematic analysis (Fig. 1). These were **Feeling safe** (Sub-themes: *Well monitored and managed*, *Accurately medicated*, *Increased understanding*, *Beneficial for me and my baby*) and, **Should be part of antenatal care** (Sub-themes: *Quick and easy*, *Convenient*, *Don't mind who does it*, *Better asthma management*).

Feeling safe

An overall feeling of increased safety was evident within the data particularly from those women who had been randomised to the intervention arm of BLT but was also reflected in the comments of control group women who had only viewed the video. Statements such as, "You feel safe. You know that [your asthma] is being taken care of" (P3F RHW) and "I like that someone is keeping an eye on it and if I have got any concerns I can call or message" (P11F JHH), indicated that the FeNO-based management process provided women with a perception of safety regarding their

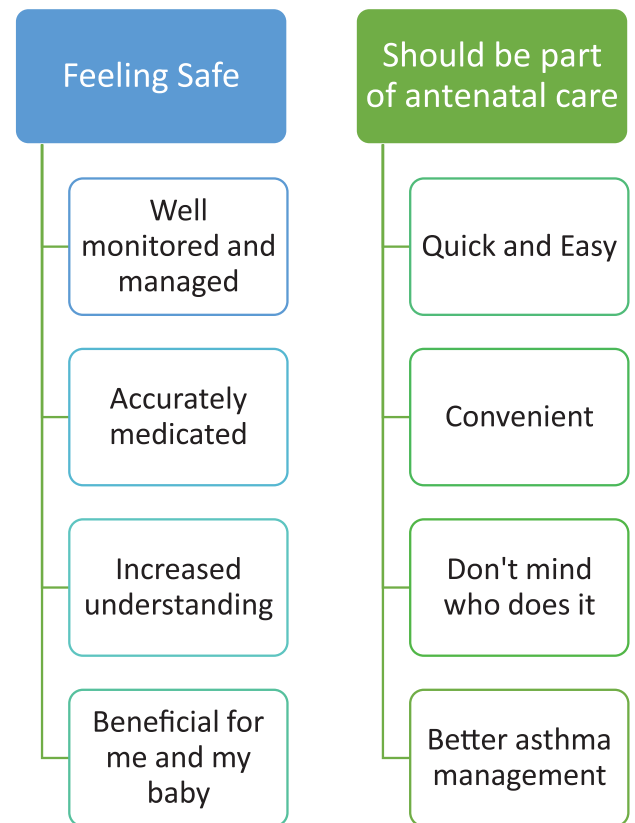


Fig. 1. Themes and sub-themes.

asthma. Women from both the FeNO and control groups discussed particular elements of the process that would make them feel safe such as "It would be beneficial to know what my inflammation levels were and how to manage it [the inflammation]" (P17C JHH).

Well monitored and managed was mentioned as an important element with those from the FeNO group stating that "you can manage your asthma and you feel safe as well" (P3F RHW), "I like that I am doing something to actively manage my asthma rather than just wait[ing] for it to flare up and then take my Ventolin" (P9F RHW) and "It is reassuring to know that someone is actually keeping an eye on it, because I don't know what is going on in there." (P18F JHH). One participant from the control group also identified the importance of monitoring asthma during pregnancy and commented, "I think that it is really important to monitor your breathing and asthma during pregnancy because it can change so rapidly" (P15C JHH). Another BLT control participant felt, "it would be beneficial to know what your levels are and to better manage it" (P17C JHH).

Being **accurately medicated** throughout the pregnancy was another element of safety the participants felt the FeNO-based management process provided. One participant stated that, she was "happy to change medication dosage because I could see [the] rationale behind it and I never left feeling concerned" (P1F JHH). Another commented that, "It's not just taking medication, it's checking if it's actually working" (P3F RHW). Furthermore, P8F JHH commented, "I like that you can see where you are at with your lungs, it is good to know...it would be good to just be on the medication you needed to be. It's good that you are not overdosing yourself".

Participants from the control group also commented on the importance of being accurately medicated, stating that, "It tests to make sure that you are on the right medications" (P13C JHH), "I feel like it is more accurate than just winging it" (P14C JHH) and "So this would help to know if it was definitely asthma or just pregnancy[related breathlessness]" (P7C JHH). Despite not experienc-

Table 2
Demographics of interview participants.

Code	Parity	Gestation weeks	Age at Asthma diagnosis	Asthma usually managed by	Medication prior to pregnancy	Current medication
P1F JHH	Primiparous	38	As a child	GP	Salbutamol and Symbicort	Salbutamol and Symbicort
P3F RHW	Primiparous	36	As a child	GP	Salbutamol and Seretide	Salbutamol and Pulmicort
P4F RHW	Multiparous	37	As an adult	GP	Salbutamol	Salbutamol and Pulmicort
P5F JHH	Primiparous	35	As an adolescent	Myself	Salbutamol	Salbutamol and Symbicort
P6F JHH	Multiparous	33	As a child	GP	Salbutamol and Seretide	Salbutamol and Symbicort
P8F JHH	Multiparous	33	As a child	GP	Prednisone and Flixotide if bad or just Salbutamol	Salbutamol
P9F RHW	Multiparous	36	As a child	Myself	Salbutamol	Salbutamol
P10F RHW	Primiparous	38	As a child	GP	Salbutamol	Pulmicort
P11F JHH	Primiparous	32	As a child	GP	Salbutamol	Salbutamol
P12F JHH	Primiparous	36	As a child	GP	Salbutamol	Symbicort and Salbutamol
P18F JHH	Primiparous	33	As a child	GP	Seretide and Salbutamol	Symbicort and Salbutamol
P2C JHH	Multiparous	32	As a child	GP/Myself	Salbutamol	Salbutamol
P7C JHH	Primiparous	37	As a child	GP	Salbutamol and Seretide	Salbutamol and Seretide
P13C JHH	Multiparous	34	As a child	GP	Pulmicort and Salbutamol	Pulmicort and Salbutamol
P14C JHH	Multiparous	32	As an adult	GP	Symbicort and Salbutamol	Symbicort and Salbutamol
P15C JHH	Primiparous	34	As an adolescent	No-one	Salbutamol	Salbutamol
P16C JHH	Multiparous	33	As a child	GP	Symbicort and Salbutamol	Salbutamol
P17C JHH	Primiparous	32	As a child	GP	Nothing	Salbutamol and Seretide

†Identifier for each interview transcript (P= pregnant woman, 1= first woman interviewed, F= FeNO randomisation group, C= Control randomisation group, JHH = hospital attended by pregnant woman – John Hunter Hospital, RHW = hospital attended by pregnant woman – Royal Hospital for Women).

Primiparous = First pregnancy Multiparous = Having 2 or more pregnancies.

GP = General Practitioner.

ing FeNO-based management, one control group participant commented that, “FeNO looks awesome...It's a good way to make sure that you're getting the right medication because it's hard to know if what you're taking is actually working for you...If you can minimise it or just be on the correct amount that is awesome”(P7C JHH).

An **increased understanding** of asthma during pregnancy was highlighted as a positive by both FeNO and control group participants. The FeNO participants stated that, “it has taught me a lot in regard to how asthma affects the baby...I have learnt more about asthma and I understand it more and I have a plan now, I know what to do” (P5F JHH). Also, one participant stated that “I now recognise the significance of asthma” (P9F RHW) and another, “this has helped me to work out what is normal and when things transition slowly you don't notice the change as much, so being aware of that is helpful” (P10F RHW). Similarly, the control participants commented that the FeNO process, “gives you a clearer understanding” (P2C JHH), “I liked that you can get to know a little bit more, in pregnancy it's normal to get a bit out of breath. When you have asthma and get out of breath, you don't really know if it is asthma related or pregnancy”(P7CJHH).

This increased understanding of asthma during pregnancy also transferred to an increased awareness of the FeNO-based management process being **‘beneficial for me and my baby’**. Participants stated, “anything that helps but doesn't have side-effects on the pregnancy is beneficial...since I was put on the preventer it has definitely improved” (P4F RHW). In regard to being beneficial for the baby, participants stated, “I never worried about [asthma] for myself but now that I know that it goes through to the baby and how dangerous it actually is, I've been monitoring it a lot more”(P5F JHH). Participants from the control group stated, “I know that if I can't breathe properly then the baby is not getting good oxygen either, so it's pretty important to look after myself so that he is getting the best chance”(P15C JHH) and also, “It would be beneficial to know that the baby is getting the right amount of oxygen levels which is something [the asthma nurse] taught me about. It would be beneficial to know what your levels are and to better manage it and it would also be beneficial for the baby”(P17C JHH).

It should be part of antenatal care

When discussing the feasibility of FeNO-based asthma management being included in antenatal care, participants overwhelmingly felt that it should be part of antenatal care. One participant stated, “100% would like this strategy to be part of my normal asthma management” (P1F JHH) and another stated, “I think it should be part of the antenatal thing because it is something you worry about, when you read about what asthma can do with pregnancy”(P3F JHH). Participants from the control group also felt that, “It should be part of normal antenatal asthma care because it doesn't hurt anyone...I would like to do it if it was offered as a routine thing”(P14C JHH), “I would be happy to do that during my pregnancy”(P7C JHH), with one stating, “I guess I would do it if it was offered as a routine thing in the clinic”(P13C JHH).

One factor supporting its feasibility, according to the participants, was that the process was or appeared to be **quick and easy**. Those in the FeNO group stated that “Everything was straightforward, quick, thorough and I got the information I needed...I had no problem using the FeNO machine”(P1FJHH). Also, “It's easy and simple, it's just breathing. You can see the results quite quickly”(P2F JHH), “the process was pretty good. It didn't take too much time”(P4F JHH), and “it's very easy and quick and it doesn't take too long...I like that it's quick and easy”(P6F JHH). Those in the control group also perceived the process to be quick and easy, stating, “It looks good”(P2C JHH), “I think the FeNO looks awesome...it looks very easy to do”(P7C JHH) and “It seems very easy and straight forward, just come in and have it done and see if I have to change anything [with my medications]”(P16C JHH).

The fact that the process was considered to be **convenient** also contributed to its feasibility, with FeNO participants stating that it “paired well with my antenatal clinic visits”(P1F JHH), “I didn't mind the extra time to check on my asthma”(P5F JHH), “It's not a problem to have a little bit extra on top of your antenatal care”(P6F JHH) and “It was convenient, it timed with my antenatal appointments so I didn't need to make an extra trip”(P11F JHH). Participants from the control group stated, “I would prefer an extra 10 min on top of my

appointments [to do the FeNO test] as opposed to having an asthma attack”(P16C JHH) and “you sit out there for so long anyway, another ten minutes is not a problem”(P17C JHH)

Participants were also asked “if implemented into the antenatal clinic which health professional would you prefer to use it?” The general consensus amongst participants was they **don’t mind who does it**, provided staff are trained in the procedure. Statements such as, “happy to have a nurse do it or midwife with training in asthma”(P1F JHH), “don’t mind who manages my asthma; GP or midwife”(P4F JHH), “I’d be happy for midwives to do the tests as part of the normal visits”(P5F JHH) and “I’d be happy for the midwives to do it. They wouldn’t be doing it if they were not trained to do it so that would be fine, it would just be part of the appointment”(P11F JHH). Those in the control group also felt that “anyone who is trained to do the test could do it. It wouldn’t matter”(P13C JHH) and “I think either a doctor or midwife should be able to administer it. Or a GP just with the relevant training, I don’t think it is something that is outside of their scope”(P15C JHH).

Participants randomised to FeNO-based asthma management in BLT believed the process should be implemented into antenatal care because it provides **better asthma management**. Statements such as “It’s the best controlled my asthma has ever been because of monitoring and FeNO”(P1F JHH) and “Anything that helps but doesn’t have side effects on the pregnancy is beneficial...last pregnancy I didn’t feel much difference but this one I definitely feel more like it was getting worse at the beginning. But since I was put on the preventer it was definitely improved”(P4F RHW) also, “It works well because I had a flare-up and I did the FeNO, my levels were all the way up and that’s when I had my medication changed and I’ve been great ever since. So it was good!”(P6F JHH). This participant also stated “I’m glad I did it because I feel better with my medication change and last time I was short of breath all the time and felt awful and I just put it down to pregnancy”(P6F JHH). Although those in the control group did not experience improved asthma management due to FeNO, they still felt that the process, “would be beneficial to know what your levels are and to better manage it”(P17C JHH); “It would cause a lot less asthma attacks if they could manage it better”(P15C JHH) and “I think the FeNO looks awesome...because it’s hard to know what you’re taking is actually working for you and this would help to know if it was definitely asthma or just pregnancy”(P7C JHH).

Discussion

This is the first study to examine the acceptability and feasibility of using FeNO-based asthma management in antenatal care, from the pregnant woman’s perspective. All participants expressed a positive acceptance of the process and support for it to become a normal part of antenatal care for pregnant women with asthma.

Viewing the video demonstration of the FeNO-based process allowed all participants to gain an understanding of how the process worked, what it meant in terms of monitoring asthma in pregnancy and titrating asthma medications to gain optimal management, and how long the process took. Importantly, those who had not personally experienced the process had similar comments about it to those who had received FeNO-based asthma management during pregnancy. All participants highlighted the regular monitoring of asthma symptoms during pregnancy, as well as increased awareness of asthma medications, their use, safety and purpose, as being a beneficial aspect of the FeNO-based management process. The opportunity for increased understanding of their asthma, and close monitoring, was expressed by the women as helping them to feel less anxious about their asthma and, increasing feelings of safety. Increasing safety was regarded as someone and something to help them look after their asthma. Participants felt that safety would be increased since they would be on the cor-

rect medication and correct dose for their needs and that would be beneficial to both themselves and their babies.

Maternal anxiety regarding asthma during pregnancy, and its effects on maternal and fetal outcomes, has been previously examined. A 2016 prospective cohort study of pregnant women with asthma, concluded that anxiety in pregnancy was associated with asthma exacerbations (RR =1.05, 95% CI: 1.01–1.08)(Zhang et al., 2016). A qualitative study by Lim et al. (2012) discussed the experiences, concerns and views of pregnant women with asthma and found that a lack of support and information regarding asthma in pregnancy (specifically what is normal, when action should be taken, and medication safety) led to anxiety among this group of women and often poor management, including medication non-adherence (Lim et al., 2012). One study attempted to address the problem of medication non-adherence in pregnancy by enrolling 114 pregnant women with asthma into a study of regular asthma review and discussion by a physician about asthma medication, throughout their pregnancy. Self-reported adherence was compared to documented adherence, defined as medical possession rate, which was calculated on prescriptions filled. This study showed a significant increase in both self-reported and actual adherence during pregnancy, concluding that being enrolled in an asthma management program during pregnancy can improve controller medication adherence.(Baarnes et al., 2016).

Further research has shown a lack of knowledge amongst health professionals providing antenatal asthma management, which leads to poor management and lack of support for pregnant women with asthma (Lim, Stewart et al. 2011, McLaughlin et al., 2016, 2020). The FeNO-based management process may be an acceptable strategy as it guides health professionals to provide accurate and therapeutic asthma management and enables pregnant women with asthma to gain a better understanding of their disease during pregnancy, which in turn reduces their anxiety. This may lead to a reduction in medication non-adherence, exacerbations and improved maternal and infant outcomes. In order to determine clinicians’ views on acceptability and feasibility of adding FeNO-based asthma management to clinical practice we have recently conducted a similar study to that reported here. This study found FeNO-based asthma management in pregnancy to be both acceptable and feasible from the perspective of clinicians providing antenatal care in NSW, Australia (McLaughlin et al., 2019).

The ease of the process was noted as another acceptable aspect of the FeNO-based strategy. Unanimously, the women interviewed stated that it either was, or appeared, an easy process. Patient acceptance of this process has previously been examined in a UK study which investigated the acceptability and ease of FeNO measurement among 22 adults and 15 children with asthma who presented to two nurse-led GP asthma clinics in south-west England (Gruffydd-Jones et al., 2007). No patients surveyed in this study found the process ‘unacceptable’, with 96% stating that it was ‘acceptable’ or ‘completely acceptable’. A Spanish study also examined the feasibility of conducting FeNO measurements in 151 children with asthma, concluding that both staff and children found the technical use of the FeNO device feasible and acceptable (Díaz Vázquez et al., 2009).

Our study participants felt that FeNO-based asthma management should be implemented into routine antenatal care. The general consensus was that the participants did not mind which health professional conducted the FeNO process as long as staff were trained in the process and it remained convenient for pregnant women. The importance of including consumers in the implementation of clinical change in healthcare is widely acknowledged and supported (Bastian 1998, Crawford and Manley, 2002). Various strategies have been used to encourage the involvement of consumers in influencing healthcare quality improvement. Most commonly, consumers have been asked to act as representatives

on advisory councils, committees and boards that make decisions about clinical programs. Alternatively, consumers were asked to provide feedback on the intended clinical change or policy prior to, during, and after implementation (Hall et al, 2018). Including consumers in all aspects of implementation design is important to further strengthen the sustainability of clinical change.

Collecting feedback from pregnant women with asthma regarding the use of the FeNO-based asthma strategy in antenatal care is therefore the first step in ensuring the process is acceptable and feasible to progress towards an implementation trial. Establishing pregnant women's perspectives on FeNO is one of the strengths of this study, since this information had not been previously collected. Transferability of results outside metropolitan tertiary referral hospital-based antenatal clinics is a limitation of this study. Another potential limitation is that all participants in this study were pregnant women with asthma involved in an asthma management trial; this may have increased the participants' general awareness of asthma in pregnancy and findings therefore may not be truly reflective of the general population of women with asthma. The pregnant women participating in this study may not have had true capacity to determine feasibility of the implementation of a FeNO-based asthma management process into the current clinical setting. To further determine feasibility therefore, clinicians have been involved in a similar study and the results recently published (McLaughlin et al., 2019).

Conclusion

In conclusion, this group of pregnant women with asthma, enrolled in an RCT of FeNO-based antenatal asthma management, found the strategy to be acceptable and regarded FeNO as feasible for implementation into routine antenatal care.

Ethical approval

This study was approved by the, Human Research Ethics Committees of the Hunter New England, Area Health Service (16/09/21/4.01) and, the University of Newcastle (h-2019-0010).

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Declaration of Competing Interest

Thank you for considering our manuscript. The acceptability and feasibility of implementing a Fractional exhaled Nitric Oxide (FeNO)-based asthma management strategy into antenatal care: the perspective of pregnant women with asthma for publication in Midwifery. We declare no conflict of interests, including financial or personal, that could inappropriately influence this work.

CRediT authorship contribution statement

Karen McLaughlin: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Writing - original draft, Visualization, Project administration. **Megan E. Jensen:** Writing - review & editing, Supervision. **Maralyn Foureur:** Methodology, Writing - review & editing, Supervision. **Peter Gibson:** Methodology, Validation, Writing - review & editing, Supervision. **Vanessa E Murphy:** Writing - review & editing.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.midw.2020.102757.

Appendix A

Video Link:



Use of FeNO in antenatal care video: Pregnant women

Appendix B

Proposed Interview Schedule Pregnant Woman with Asthma

- 1 Tell me about your diagnosis of asthma
 - Who diagnosed you with asthma?
 - How was the diagnosis made?
 - When was the diagnosis made?
- 2 Tell me about your pregnancy
 - How many weeks pregnant are you?
 - Is this your first pregnancy?
 - If not your first pregnancy did you have an asthma diagnosis for your last pregnancy?
 - Who are you currently seeing for your antenatal care?
 - Please describe how your asthma has been managed during this or previous pregnancies.
 - What advice were you given in regard to asthma and pregnancy?
 - What or who was your main source of advice regarding asthma management during pregnancy?
- 3 Tell me what you know about the breathing test used to measure FENO and how that is being used in the care of pregnant women with asthma.
- 4 After watching the FENO-Based asthma management strategy video do you have a better understanding of the FENO-based asthma management strategy?
- 5 How does this strategy differ to the asthma management you have previously received?
- 6 Do you think you would like your asthma to be managed this way during your pregnancy?
- 7 What do you like about this way of managing asthma in pregnancy?
- 8 What do you dislike about this way of managing asthma in pregnancy?
- 9 Would you recommend that your antenatal care provider use this to manage your asthma?

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