Implementation of a Clinical Decision Laboratory Ordering Algorithm for Preeclampsia: A Quality Improvement Initiative

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Abstract

Objective: Pregnant women with suspected or diagnosed preeclampsia receive laboratory investigations. Our institutional protocols were outdated and not evidence based. However, guidelines lack clear direction to support cost-effective use. We aimed to reduce unnecessary laboratory tests, while supporting physicians with investigation selection.

Methods: A quality improvement (QI) approach was used to analyze the ordering process in the obstetrics wards of a tertiary care centre. Health care providers were surveyed on their laboratory ordering practices, and their responses corroborated with chart reviews. An algorithm for ordering preeclampsia investigations was developed by a multidisciplinary team, implemented, and posted on the wards. Pocket aides were also distributed, and the algorithm tool was supported by educational seminars. Laboratory usage volume and costs were analyzed pre- and post-intervention. Post-intervention impact surveys, informal interviews, and chart reviews were performed in plan-do-study-act (PDSA) cycles.

Results: Most health care providers ordered broad panels of investigations and re-evaluated patients at inconsistent intervals. Almost none were aware of the laboratory costs associated with this testing. Most respondents acknowledged that some of the investigations they ordered did not affect patient care. Baseline data (Sept 2016–Aug 2017) showed 2923 tests ordered monthly (CAD$18 306). Post-intervention data (Sept 2017–Aug 2019) revealed a 39.9% reduction in costs related to blood tests (a savings of CAD$7304/mo), particularly those tests of lower clinical utility. The performance of essential investigations, such as measurement of creatinine levels, were similar pre- and post-intervention, and thus acted a control measure. The effects of this intervention were sustained.

Conclusions: This simple and inexpensive intervention reduced unnecessary ordering of preeclampsia investigations. This resulted in annualized savings of CAD$87 643 and reduced iatrogenic blood loss, with no evidence of harm. Efforts to scale and spread this clinical tool will further improve health care delivery for pregnant patients.

Keywords: pre-eclampsia, algorithms; quality improvement

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Résumé

Objectif : Des analyses de laboratoire sont réalisées chez les femmes enceintes en cas de pré-éclampsie soupçonnée ou diagnostiquée. Les protocoles de notre établissement étaient désuets et non fondés sur des données probantes. De plus, les directives ne fournissent pas une orientation claire favorisant une utilisation rentable. Nous avons donc visé à diminuer le nombre d'analyses de laboratoire inutiles, tout en soutenant les médecins dans la sélection des analyses.

Méthodologie : Une stratégie d'amélioration de la qualité a été utilisée pour analyser le processus de requête au sein des services d'obstétrique d'un centre de soins tertiaires. Les fournisseurs de soins de santé ont été interrogés sur leurs pratiques de requête d'analyses de laboratoire, et leurs réponses ont été corroborées par l'examen des dossiers. Une équipe multidisciplinaire a créé un algorithme pour les requêtes d'analyses liées à la pré-éclampsie, l'a mis en œuvre puis diffusé dans les services. De plus, des aide-mémoire de poche ont été distribués, et des séminaires de formation ont été donnés pour expliquer l'outil algorithmique. Les coûts et le volume d'utilisation des analyses de laboratoire ont été étudiés avant et après la mise en œuvre de la mesure. Des analyses d'impact après la mise en œuvre, des entrevues informelles et des examens de dossiers ont été effectués dans le cadre des cycles de Shewhart (PCDA).

Résultats : La plupart des fournisseurs de soins de santé envoyaient des requêtes comprenant de nombreuses analyses et réévaluaient les patientes à des intervalles irréguliers. Presque aucun d'entre

eux ne connaissait les coûts de laboratoire liés à ces analyses. La plupart des répondants ont reconnu que certaines des analyses qu'ils avaient demandées n'avaient pas eu d'incidence sur les soins prodigués à la patiente. Les données de base (de septembre 2016 à août 2017) révèlent que 2 923 analyses étaient demandées chaque mois (18 306 $ CA). Les données après la mise en œuvre (de septembre 2017 à août 2019) témoignent d'une réduction de 39,9 % des coûts liés aux analyses sanguines (une économie de 7 304 $ CA par mois), en particulier les analyses de faible utilité clinique. Les résultats des analyses essentielles, notamment le dosage de la créatinine, étaient semblables avant et après la mise en œuvre et ont donc servi de mesure de contrôle. Les effets de cette mesure ont été durables.

Conclusions : Cette mesure simple et peu coûteuse a réduit les requêtes d'analyses inutiles pour la pré-éclampsie. Elle a engendré des économies annualisées de 87 643 dollars canadiens et réduit les pertes sanguines iatrogènes, sans indication de conséquence défavorable. Les efforts visant à élargir et à diffuser cet outil clinique amélioreront davantage la prestation de soins de santé aux patientes enceintes.

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INTRODUCTION

Hypertensive disorders of pregnancy remain leading causes of both maternal and fetal complications in Canada.[1] In addition to monitoring for clinical signs and symptoms, pregnant women suspected of having pre-eclampsia (PEC) undergo laboratory investigations for both diagnosis and surveillance.

The Lois Hole Hospital in the Royal Alexandra Hospital in Edmonton, Alberta, is a tertiary care centre with a large catchment area and cares for most high-risk pregnancies in northern Alberta. Over 7500 deliveries occur at the centre annually. Women with suspected or confirmed PEC at our institution undergo a bundled pregnancy-induced hypertension (PIH) investigation panel, which includes complete blood count with differential (CBC-D), alanine aminotransferase (ALT), aspartate aminotransferase (AST), creatinine, uric acid, urinalysis, urine protein-to-creatinine ratio, fibrinogen, international normalized ratio (INR), activated partial thromboplastin time (aPTT), D-dimer, electrolytes, and urea. However, these tests do not have equal clinical utility for patients with preeclampsia, whether suspected or confirmed. For example, fibrinogen, INR, and aPTT are unnecessary in the absence of suspected coagulopathy, especially if platelet count is normal.[2] Uric acid[3] and urine protein-to-creatinine ratio[1] are diagnostic but not prognostic; therefore, once positive, there is no need for the test to be repeated. Electrolytes and urea are not clinically diagnostic for PEC, and creatinine is a more reliable alternate method of assessing renal function. The role of D-dimer in PEC is still to be determined.[4] In PEC, AST and ALT are highly correlated, and ALT is a more specific liver marker. Although current guidelines[1] list the aforementioned possible PEC investigations, they provide no direction in test selection based on clinical setting. Likewise, we are not aware of any published clinical decision-making tools for the selection of PEC investigations. Therefore, we sought to develop a clinical decision-making tool for the selection of PEC investigations, with the aim of reducing unnecessary testing.

We aimed to reduce laboratory tests ordered for PEC by 30% on 3 antepartum wards within the first year of the project. Furthermore, we aimed to abandon the use of the term "PIH," as suggested by the Canadian hypertension in pregnancy guideline, because "PIH" is commonly intended to mean "preeclampsia" but technically means "gestational hypertension."[1]

METHODS

The project was conducted at the Lois Hole Hospital in the Royal Alexandra Hospital, which is a tertiary-level care facility with a large catchment area and complex population. Three obstetrics wards were included in the intervention, comprising all antepartum care at the Lois Hole Hospital.

The outpatient assessment room acts as an obstetric emergency department and contains 11 beds; the inpatient antepartum ward has 26 beds; and the labour and delivery ward has 16 beds and is the site of obstetrical deliveries and acute care. Each ward is staffed with nurses, unit clerks, attending physicians, residents, and medical students. In each ward, residents order the majority of laboratory investigations; however, PEC investigations are frequently ordered proactively by nurses in the outpatient assessment room. Residents at our centre consistently use pocket cards as job aides for writing orders, and nursing protocols are based on posted investigation panels and convention.

Quality improvement tools such as a cross-functional process map, a force field diagram, and a cause-and-effect diagram identified process strengths and gaps within our triage unit, labour and delivery, and antepartum wards. The project team reviewed the literature and current best practices to develop a standard approach to PEC investigations. Frontline health care providers, including physicians,

residents, nurses, and unit clerks, were invited to complete a survey regarding laboratory test ordering practices (online Appendix A). The pre-intervention survey was used to validate whether there was a problem and to reach a consensus on the investigations that were deemed to be useful. Baseline laboratory usage data for PEC investigations were collected. Survey and laboratory usage data were corroborated with a prospective chart review.

Our intervention was intended to be practical, logical, feasible, and positioned early in the clinical process to support diagnostic reasoning for PEC investigation orders. Laboratory test volume and costs were analyzed pre- and post-intervention. Post-intervention, charts were reviewed for any changes, and a survey about the intervention was conducted. The post-intervention survey served to evaluate the feasibility of the intervention and the impact of measures to promote adoption of the intervention as the "study" part of the plan-do-study-act (PDSA) cycle, working toward refinement of the intervention.

We conducted 3 sets of chart reviews to assess physician ordering practices. The first set of chart reviews was completed pre-intervention, the second was completed after the first PDSA cycle, and the third (and final) was completed on May 15, 2018, to determine project sustainability. All patients who were admitted to obstetric wards on chart review dates and who had suspected or confirmed PEC, as determined by the charge nurse, were included.

This study used the Model of Improvement theoretical framework, wherein experimentation via PDSA cycles and practical experience leads to continuous improvement.[5] Based on this framework, the multidisciplinary team developed a clinical decision-making tool to guide the selection of PEC investigations.

Institutional convention for patients suspected of or confirmed as having PEC was to order PIH laboratory tests. These included CBC-D, ALT, AST, creatinine, uric acid, urinalysis, urine protein-to-creatinine ratio, fibrinogen, INR, aPTT, D-dimer, electrolytes, and urea. These were commonly ordered daily for expectantly managed patients and every 8 hours for patients requiring imminent delivery. We designed an algorithm for ordering PEC investigations (online Appendix B).

Our multidisciplinary team consisted of an obstetric medicine physician and fellow, maternal fetal medicine physician and residents, obstetrician, laboratory biochemist, and clinical nursing educator. Investigations of low clinical value were identified using available literature and survey results. These included white blood cell differential, electrolytes, urea, D-dimer, and coagulation studies such as PTT, INR, and fibrinogen. The multidisciplinary team designed a decision-making algorithm to reduce the overuse of low-utility tests and promote judicious use of resources. The algorithm was posted on the obstetrics triage and antepartum wards. The algorithm also was available to frontline nurses, who frequently ordered laboratory tests before patients were seen by a physician. Pocket-sized algorithm cards were distributed to obstetrics residents, who order the majority of PEC investigations. Obstetrics residents at our institution use existing pocket cards to guide basic clinical practice, so incorporating this algorithm required little change. Health care providers, including ward nurses, physicians, and unit clerks, were invited to educational seminars to support the implementation of this decision-making tool. The algorithm was made available to nurses for use as a protocol. Project posters were placed in work areas and lounges to raise awareness of the issues and to promote algorithm use.

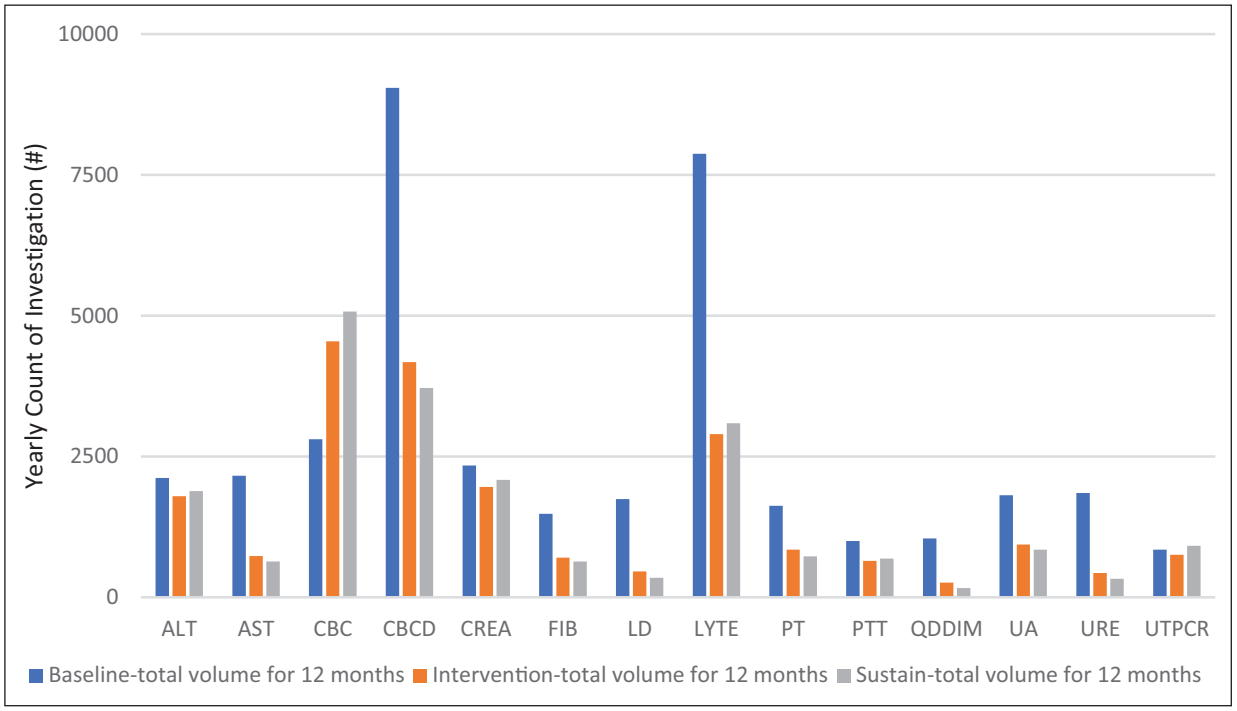
Post-intervention impact surveys and chart reviews were conducted to evaluate the adoption of the algorithm, and laboratory usage data for the 3 study wards were analyzed pre- (September 2016 to August 2017) and post-intervention (September 2017 to August 2019). These laboratory usage data captured all investigations ordered in the conventional PIH labs panel, including those intended for the workup of different diagnoses.

All patients who were diagnosed as having, or suspected to have, PEC had laboratory testing performed per the attending physician's discretion. There was no restriction on test availability, with the PEC algorithm being provided as a decision-making tool.

RESULTS

An initial survey about the practice of ordering the PIH test panel, clinical opinions about laboratory test costs, and necessary tests for PEC was sent to the Department of Obstetrics physicians, residents, ward nurses, and unit clerks, as well as obstetric medicine physicians. Forty-five people responded: 17 staff physicians (37.8%), 16 residents (35.6%), 11 nurses (24.4%), and 1 medical student. The survey data indicated most providers ordered broad panels of investigations and inconsistently re-evaluated frequency, and almost none were aware of laboratory costs (online Appendix A). About half of respondents acknowledged that some investigations they ordered did not affect patient management and listed the tests that they believed were not clinically needed.

Figure 1. Laboratory investigations ordered at baseline (September 2016 to August 2017), intervention (September 2017 to August 2018), and sustainment (September 2018 to August 2019).



CBCD: complete blood count with differential; CREA: creatinine; FIB: fibrinogen; LYTE: electrolytes; QDDIM: quantitative D-dimer; UA: urinalysis; URE: urea; UTPCR: urine protein-to-creatinine ratio.

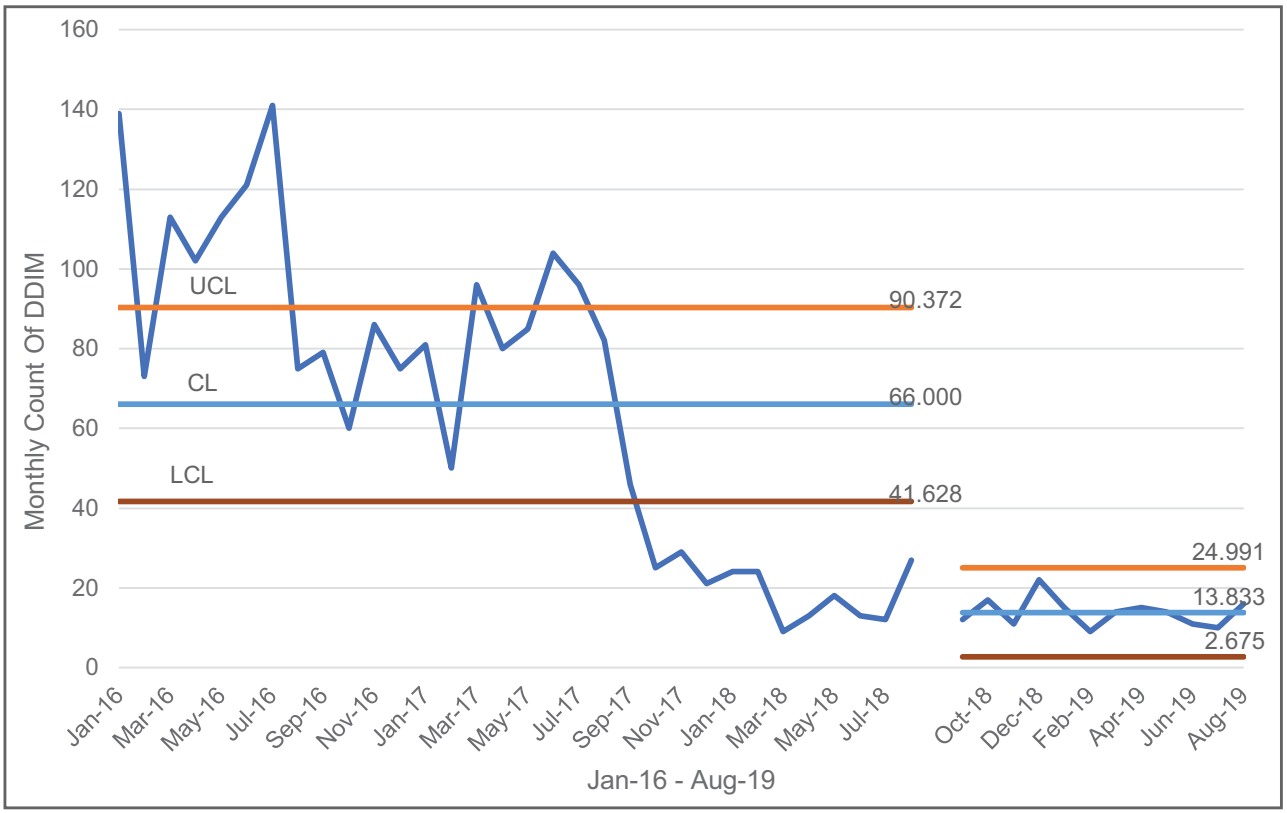
Our quality improvement project was launched on the obstetrics wards on September 5, 2017, and the first "in-service" education with nursing took place on September 20, 2017. Laboratory test order data pre-intervention (for 1 year prior to September 2017) were compared with laboratory use data post-intervention for 1 year, as well as in a second year as the sustainment phase (Figure 1).

The overall reduction in laboratory costs post-intervention was CAD$7304 monthly, or $87 643 annualized.[6] Of investigations targeted for reduction owing to low clinical utility, urea decreased by 77.8% (CAD$558/month), and D-dimer decreased by 78.1% (CAD$951/month) (Figure 2). Providers were less likely to order both AST and ALT. ALT volumes were stable pre- and post-intervention (Figure 3), whereas AST volumes declined by 66.0% (Figure 4). As intended, there was a 52.6% reduction in CBC-D and a commensurate 86.4% increase in CBC without differential (online Appendix C), with accompanying cost savings. Investigations recommended in the algorithm, namely ALT and creatinine, were stable both pre- and post-intervention. These investigations act as a control measure and indicate that our intervention did not reduce the ordering of appropriate laboratory investigations. (Figure 3).

The pre-intervention chart review (12 charts) revealed routine ordering of PIH panels with bundled investigations by nurses in the patient assessment and triage ward. The first post-intervention chart review (11 charts) showed that the PEC investigations ordered by nurses were reduced and generally aligned with the algorithm. In contrast to pre-intervention, physicians started ordering PEC investigations by writing the names of specific tests, most of which were aligned with our PEC algorithm. In the third and final chart review (10 charts), 18% of charts contained the old order for PIH labs, versus 32.4% in our initial pre-intervention chart review. The third chart review found limited use of the coagulation profile and rare usage of electrolytes and urea tests. AST use decreased dramatically, but all women had at least one liver assessment using ALT. All patients received, at a minimum, the basic panel consisting of CBC, ALT, and creatinine, suggesting positive change acceptance of the PEC algorithm at our hospital. This chart review did not identify any unintended consequences of the intervention.

A post-intervention care provider survey was distributed, and 22 providers responded, with the majority (90.9%) being obstetrics residents (online Appendix D). Of the 22 respondents, 21 (95%) indicated they use the investigation

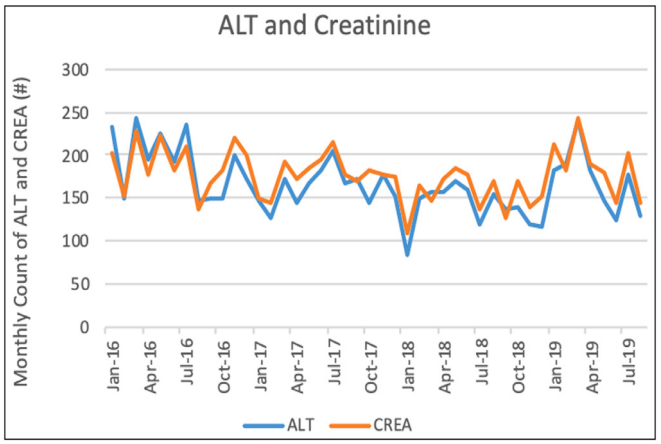
Figure 2. Run-chart for D-dimer—a test deemed unnecessary in routine preeclampsia investigation.



CL: centre line (mean); LCL: lower confidence limit at 2 standard deviations below the mean; UCL: upper confidence limit at 2 standard deviations above the mean.

algorithm. Using a scale of 1 to 5, respondents indicated that they believed the algorithm was very easy to use (16 of 22; 72.7%) or easy to use (6 of 22; 27.3%). Most (81.8%) believed that the algorithm was patient-centred. Most respondents reduced or stopped ordering tests that are considered low clinical utility, and all respondents believed use of the algorithm was sustainable.

Figure 3. Run-chart for alanine aminotransferase and creatinine—tests that are not changed by the algorithm.



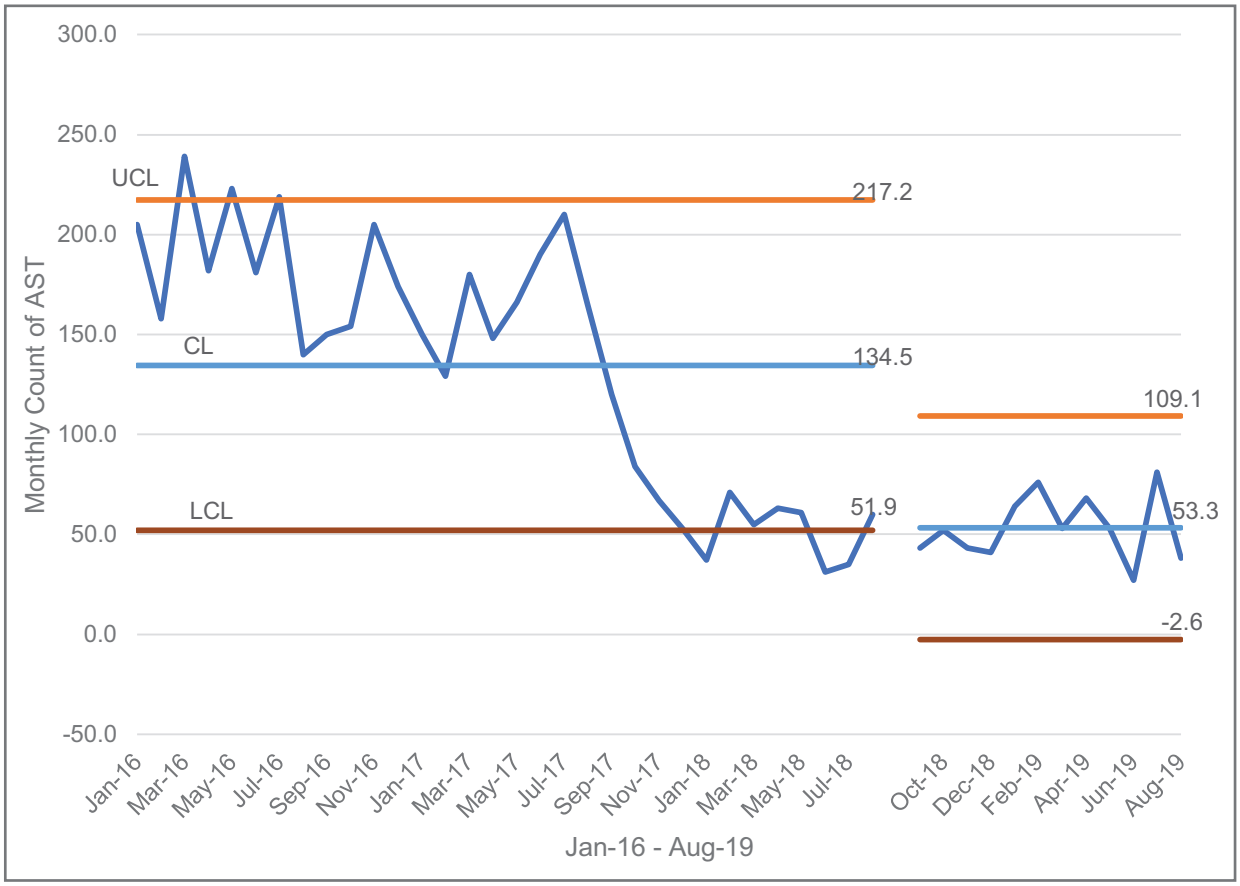
ALT: alanine aminotransferase; CREA: creatinine.

Eight of 12 survey respondents believed the project resulted in no negative consequences. One mentioned initial conflict with nurses and staff but indicated that this conflict had been resolved. Two respondents noted that, at times, sicker patients were not getting additional required investigations (i.e., the basic PEC panel was being done as opposed to the more comprehensive severe PEC/hemolysis, elevated liver enzymes, and low platelets panel) and noted a need for reassessment of investigation frequency with clinical deterioration. Based on this feedback as part of the PDSA cycle, the algorithm was revised to reinforce the importance of clinical judgement where a suggested frequency of investigations was articulated based on the clinical situation (Figure 5).

DISCUSSION

Overuse of laboratory investigations leads to unnecessary health care system costs and contributes to iatrogenic anemia. We identified inappropriate use of PEC investigations at the Lois Hole Hospital. Applying quality improvement

Figure 4. Run-chart for aspartate aminotransferase—a test deemed unnecessary, as replaced by alanine aminotransferase.



CL: centre line (mean); LCL: lower confidence limit at 2 standard deviations below the mean; UCL: upper confidence limit at 2 standard deviations above the mean.

methodology, we developed a clinical decision-making tool to assist in the appropriate ordering of PEC investigations. This reduced laboratory usage costs without compromising patient safety. The interventions led to 39.9% reduction in laboratory tests ordered for PEC, resulting in an approximate annual savings of CAD$87 643.

The volume of low-utility clinical investigations dropped abruptly after our intervention, and the results were sustained (Figures 1, 2, and 4). Given that all laboratory tests ordered on our 3 targeted obstetrics wards were included in our project, it is unlikely that any women with PEC were excluded.

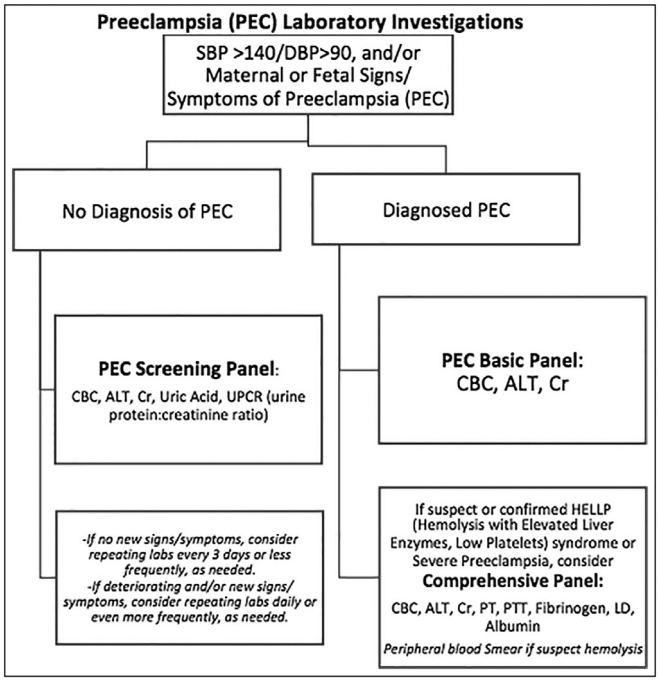
Verbal feedback and chart reviews guided our PDSA cycles, which improved project sustainability and impact. Pre- and post-intervention chart reviews provided qualitative information on PEC investigation ordering practices. In particular, the chart review provided information on the use of the term "PIH labs" and whether components of the panel were individually written as orders.

The project was inexpensive and was incorporated easily into existing physician and nursing processes. The algorithm's inclusion within resident pocket cards and nursing protocols helped sustain change.

Traditionally, our institution used bundled PIH lab panels, which were ordered for all patients with suspected or diagnosed PEC. These were often ordered by nurses in triage. The sustained impact of the intervention was due to the incorporation of the algorithm into pre-existing practices. Because most PEC investigations were ordered pre-emptively by nurses prior to physician assessment, readily available job aides directed and validated the adoption of more judicious ordering practices. This was especially impactful given that previous ordering practices were based largely on institutional culture. This project may have limited generalizability to other hospitals with different processes and practice patterns.

All investigations ordered on the obstetrics ward were included in the pooled data. Laboratory investigations were infrequently ordered by antepartum obstetrics other than for

Figure 5. Revised clinical decision algorithm for preeclampsia investigations.



ALT: alanine aminotransferase; CBC: complete blood count; Cr: creatinine; DBP: diastolic blood pressure; LD: lactate dehydrogenase; PT: prothrombin time; PTT: partial thromboplastin time; SBP: systolic blood pressure.

investigation of hypertensive disorders of pregnancy, so most of the investigations used are relevant to our intervention. However, a limitation of this study is that it does not differentiate between tests ordered for workup of PEC and tests ordered for the workup of other diagnoses (e.g., a complete blood count not for PEC but for sepsis). This may underestimate the true effect size of the intervention. However, this proportion of investigations used for non-PEC diagnoses should not have significantly changed pre- and post-intervention, so the validity of the results should not be affected.

Another limitation is that informal discussions about the project may have led clinicians to change their behaviour prior to our intervention date and the formal introduction of the algorithm. This may lead to underestimation of the intervention effect size.

CONCLUSION

We developed and introduced a PEC investigation algorithm that was simple and inexpensive to implement and substantially reduced laboratory usage costs and blood draws. Our intervention showed sustained results beyond a year and resulted in annualized savings of CAD$87 643. In addition, "PEC" has now replaced "PIH" to refer only to preeclampsia and not also encompass gestational hypertension. Given the algorithm's simplicity and effectiveness, we encourage other institutions to adopt this algorithm.

The next step for the PEC algorithm is to be shared widely throughout the Edmonton Zone to further standardize laboratory investigations for preeclampsia across the health region and to be scaled and spread across Alberta. One other hospital in the Edmonton Zone has already adopted the PEC algorithm, and we will evaluate the impact at that hospital. Interest in the PEC algorithm is rising due to our sharing it at national and international conferences; as such, colleagues from other centres in Canada are also interested in adapting the algorithm within their local hospitals. Future efforts will explore how our PEC diagnostic ordering tool can be included in clinical practice guidelines to further affect health care service delivery for pregnant patients.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at 10.1016/j.jogc.2020.03.016.

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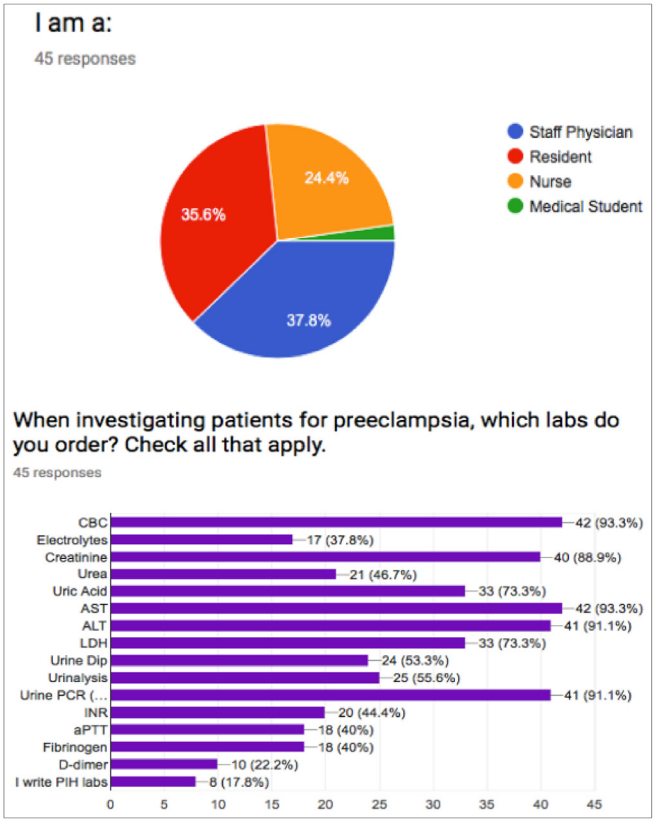
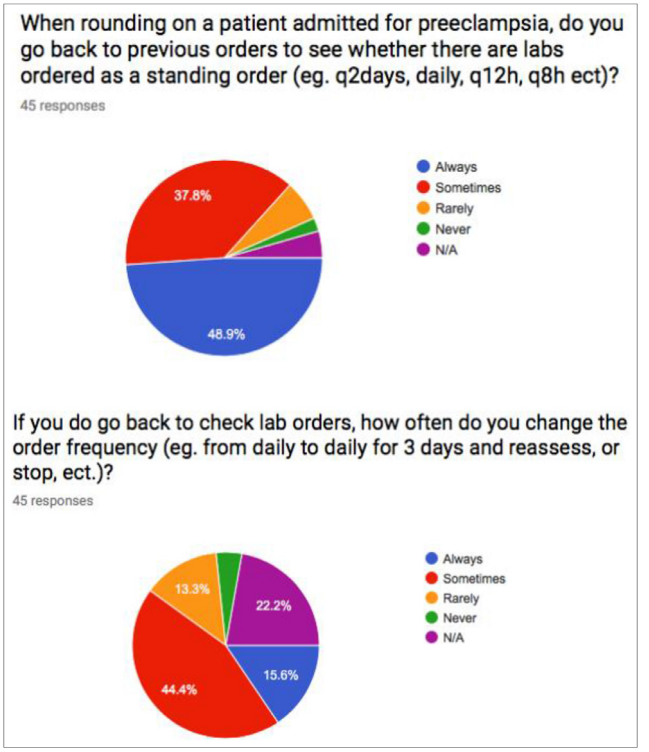
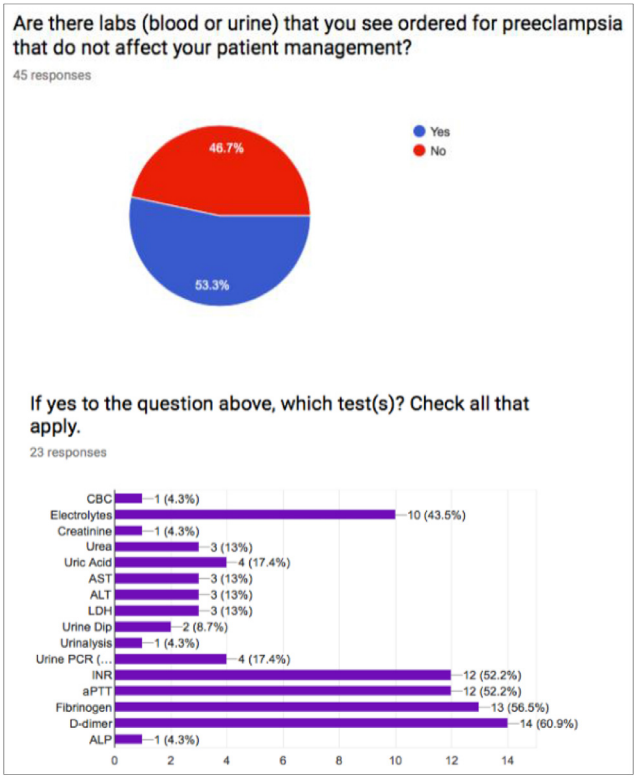
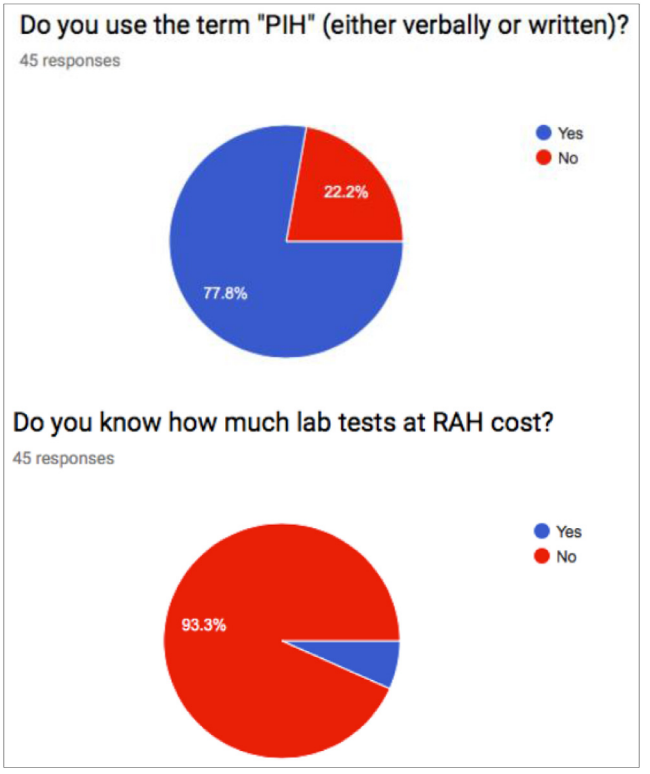
APPENDIX A: PRE-INTERVENTION HEALTHCARE PROVIDER SURVEY DATA

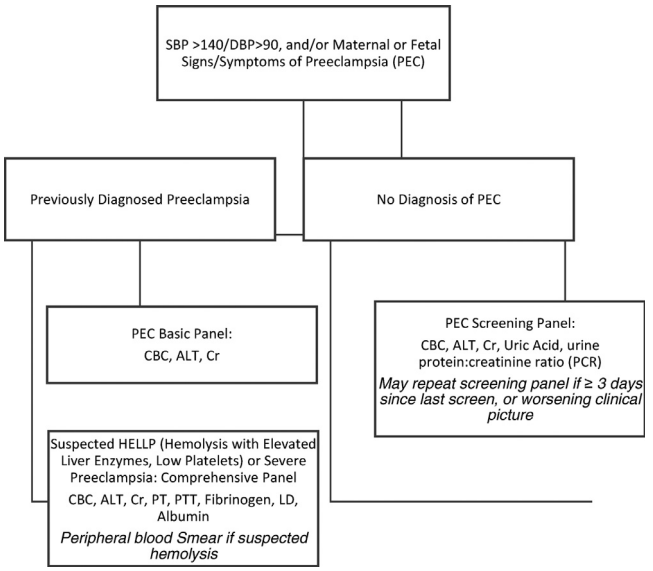




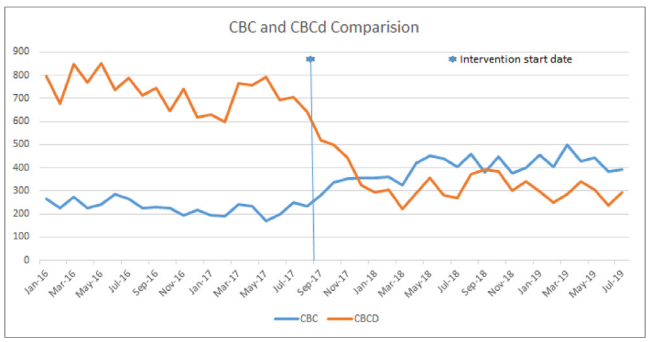




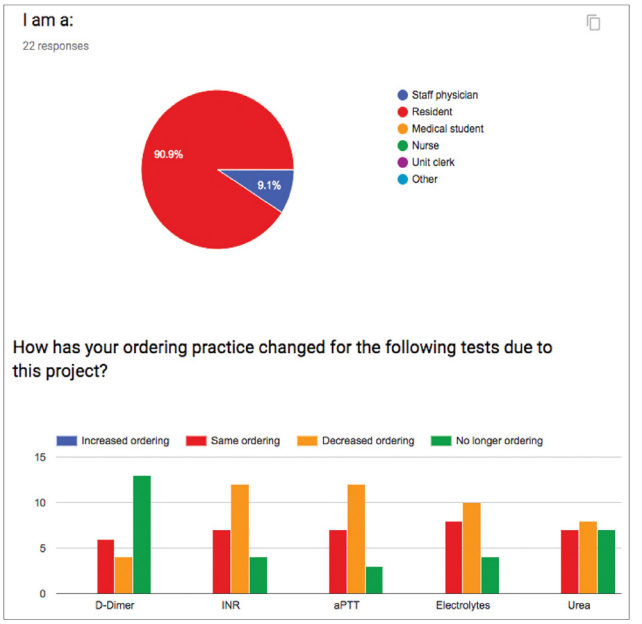
APPENDIX B: ORIGINAL ALGORITHM FOR PREECLAMPSIA INVESTIGATIONS

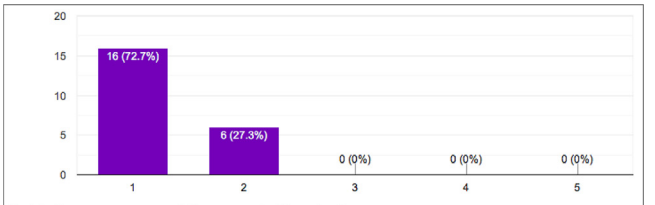


APPENDIX C: RUN-CHART FOR CBC AND CBC WITH DIFFERENTIAL (CBCD) SHOWING CBC ORDER REPLACED THE CBCD, AS THE DIFFERENTIAL WAS DEEMED UNNECESSARY



APPENDIX D: POST-INTERVENTION HEALTHCARE PROVIDER SURVEY DATA





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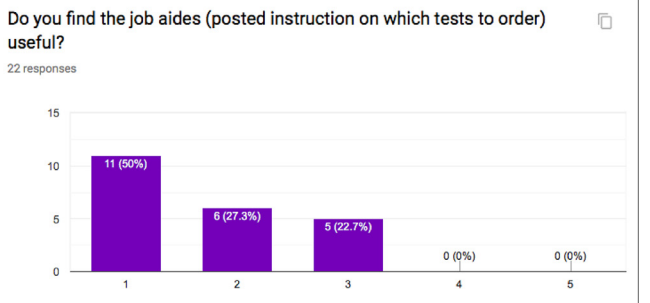

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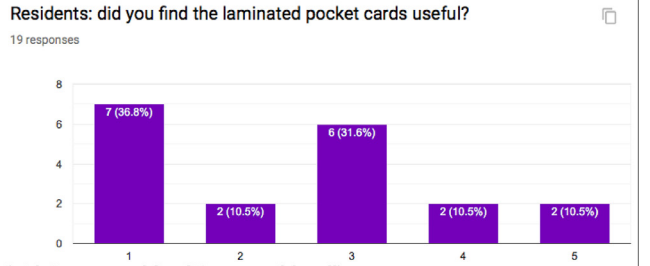

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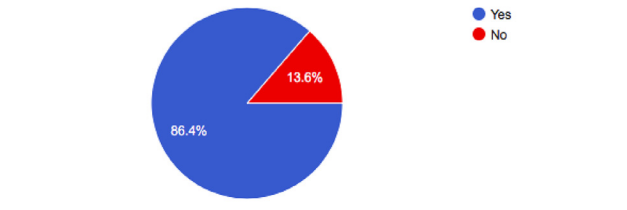
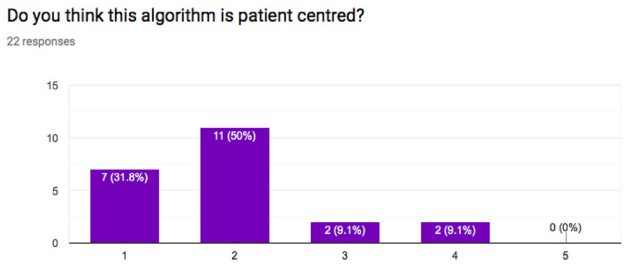
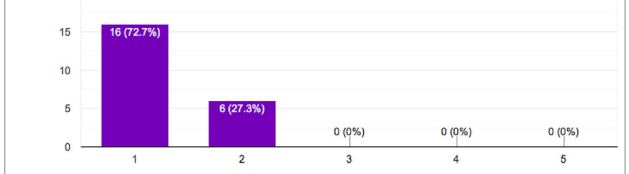




(with 1 = patient-centered and 5 = not patient-centered)



(with 1 = very sustainable and 5 = not sustainable at all)