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RESEARCH

Impact of bariatric surgery on hypertensive disorders in pregnancy: retrospective analysis of insurance claims data

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ABSTRACT

Objective To determine whether women who had a delivery after bariatric surgery have lower rates of hypertensive disorders in pregnancy compared with women who had a delivery before bariatric surgery.

Design Retrospective cohort study.

Setting Claims data for 2002-6 from seven insurance plans in the United States.

Participants 585 women aged 16-45 who had undergone bariatric surgery, had at least one pregnancy and delivery, and had continuous insurance coverage during pregnancy plus two weeks after delivery.

Main outcome measure Hypertensive disorders in pregnancy defined with ICD-9 codes. The independent variable was the timing of delivery in relation to bariatric surgery, classified as deliveries before and after surgery. We used logistic regression to calculate odds ratios and confidence intervals for each type of hypertensive disorder in pregnancy.

Results Among the 585 women who had undergone bariatric surgery and had a delivery, 269 delivered before surgery and 316 delivered after surgery. Gastric bypass was the surgery in 82% (477) of all women. Women who delivered before surgery were younger at the time of delivery (mean age 31.3 *v* 32.5) but had higher rates of pre-existing diabetes and gestational diabetes mellitus. Compared with women who delivered before surgery, women who delivered after surgery had substantially lower rates of pre-eclampsia and eclampsia (odds ratio 0.20, 95% confidence interval 0.09 to 0.44), chronic hypertension complicating pregnancy (0.39, 0.20 to 0.74), and gestational hypertension (0.16, 0.07 to 0.37), even after adjustment for age at delivery, multiple pregnancy (that is, twins or more), surgical procedure, pre-existing diabetes, and insurance plan.

Conclusion In this retrospective analysis of US women, bariatric surgery was associated with lower rates of hypertensive disorders in subsequent pregnancy.

INTRODUCTION

Obesity is a major public health concern worldwide.[1] In the United States in 1999-2004, about a third of all women of reproductive age were obese (body mass index (BMI) ≥30) and 6-8% had class III obesity (BMI ≥40).[2] The prevalence of class III obesity rapidly increased between 1990 and 2000 and was two times higher in women than in men for each year.[3]

Obesity is a risk factor for adverse perinatal outcomes,[4] including gestational diabetes mellitus,[5] pre-eclampsia,[6 7] and congenital anomalies.[8] The risk of caesarean delivery increases with increasing BMI and is almost three times higher for women with class II obesity (BMI ≥35) than for women with a normal BMI.[9] In addition, obesity in pregnancy is associated with increased use of healthcare services.[10]

Hypertensive disorders in pregnancy complicate about 7% of all pregnancies in the US[11] and are a common cause of maternal morbidity and mortality.[12] They are defined as chronic hypertension that precedes and might continue during pregnancy, mild or severe pre-eclampsia, eclampsia, pre-eclampsia superimposed on chronic hypertension, and gestational hypertension.[13] Although the pathophysiology of these disorders is complex and not yet completely understood, interventions that reduce obesity have the potential to decrease their incidence and associated complications.[14]

Bariatric surgery is the most effective treatment for obesity, resulting in considerable weight loss and improvement in many comorbidities.[15] US insurance companies require potential candidates for bariatric surgery to meet criteria for either class III obesity or class II obesity with associated high risk comorbid conditions, such as type 2 diabetes or obstructive sleep apnoea.[16] Data from the US Nationwide Inpatient Sample for 1998-2005 showed that women accounted for 83% of all bariatric surgery procedures in those aged 18-45.[17] While there is some evidence that bariatric surgery reduces the risk of perinatal complications,[17-19] few studies have examined large national data sources or examined the impact on all severities of hypertensive disorders in pregnancy.

We conducted a retrospective analysis of claims data from seven BlueCross BlueShield insurance plans to assess the relation between bariatric surgery and hypertensive disorders in pregnancy. We hypothesised that women who delivered after bariatric surgery would have lower rates of hypertensive disorders in pregnancy compared with women who delivered before surgery.

METHODS

Study design

We performed a retrospective analysis using insurance claims data for 2002-6. We identified claims for pre-eclampsia and eclampsia, chronic hypertension complicating pregnancy, pre-eclampsia or eclampsia superimposed on hypertension, and gestational hypertension diagnoses in a sample of women who had at least one delivery and had undergone bariatric surgery. We examined the proportion of hypertensive disorders in pregnancies after surgery compared with before surgery. We used women who underwent surgery after delivery as the comparison group because all patients undergoing bariatric surgery have met the criteria for either class II obesity with high risk comorbid conditions or class III obesity, and the dataset did not include data on BMI, which could have allowed us to identify a different comparison group of obese women.

Data source

We accessed claims data from seven BlueCross BlueShield health plans, providing coverage in seven states: Tennessee, Western Pennsylvania, Michigan, North Carolina, the city of Philadelphia in Pennsylvania, South Dakota and Iowa (included in same plan), and Hawaii. The dataset included insurance claims information, as well as variables for age, but did not consistently include height or weight to calculate BMI, or information on gravidity or parity. Inclusion in the dataset required at least one of the following criteria at any point during 2002-6: completed health risk assessment or other survey; claim for a diagnosis of obesity; claim for bariatric surgery (see appendix A on bmj.com); prescription claim for a weight reduction medication; or diagnosis code of hyperlipidaemia, type 2 diabetes, sleep apnoea, gallbladder disease, or metabolic syndrome. These diagnoses were identified in the claims by common procedural terminology codes, ICD-9-CM (international classification of disease, ninth revision, clinical modification codes), national drug codes, or diagnosis related group codes. We acquired data on enrolment files for administrative data; benefits information to determine medical coverage; and inpatient, outpatient, and pharmacy claims records containing ICD-9 diagnosis, common procedural terminology codes, prescription national drug codes, and costs and charges (submitted, allowed, and paid).

Selection of study sample

We selected women who had codes within the coverage period for both bariatric surgery (see appendix A on bmj.com) and a delivery, defined as one or more live births or a pregnancy loss after 25 weeks' gestation (see appendix B on bmj.com), with an inpatient point of service code.

For women with more than one delivery date, we calculated the time between dates to try to determine if these were claims from the same pregnancy or if the woman had more than one pregnancy during 2002-6. For each possible pregnancy, we selected the actual delivery date as the date of service with the most delivery records/claims.

For each woman, the delivery date(s) was compared with the date of the claim for bariatric surgery. We excluded implausible delivery dates: either less than 280 days after bariatric surgery or less than 31 days before surgery. Women were classified into groups who delivered before or after surgery based on date of delivery in relation to surgery. If a woman had two or more deliveries, or had a delivery both before and after surgery, we selected the delivery closest to her bariatric surgery and classified the woman on the basis of this delivery.

We restricted our analyses to women aged 16-45 at the time of delivery who had continuous insurance coverage during pregnancy (calculated as delivery date minus 40 weeks) plus two weeks after delivery to capture the diagnosis codes for hypertensive disorders in pregnancy, the outcomes of interest. In a separate subgroup analysis of women who had deliveries both before and after surgery we did not apply the requirement of continuous insurance coverage but the rest of the inclusion criteria were the same.

Definition of outcomes of hypertensive disorders in pregnancy

Our outcomes of interest were diagnoses of hypertensive disorders in pregnancy during the pregnancy (40 weeks before delivery) plus the two weeks after delivery. We defined "pre-eclampsia" and as the presence of one or more ICD-9 codes for "mild" or "severe pre-eclampsia" (either 642.4x or 642.5x). "Eclampsia" was defined by its ICD-9 code (642.6x). We created mutually exclusive definitions for mild pre-eclampsia, severe pre-eclampsia, or eclampsia, which were classified by the presence of the more severe diagnosis code. We defined "chronic hypertension complicating pregnancy" as one or more ICD-9 codes for "benign essential hypertension complicating pregnancy" (642.0x) or "other pre-existing hypertension complicating pregnancy" (642.2x). We defined "gestational hypertension" as one or more ICD-9 codes for "transient hypertension in pregnancy" (642.3x) or "unspecified hypertension during pregnancy" (642.9x), as long as the woman did not also have chronic hypertension complicating pregnancy. The outcome of "pre-eclampsia or eclampsia superimposed on pre-existing hypertension" required the presence of its ICD-9 code (642.7x). In addition, women who met the definition for pre-eclampsia or eclampsia and then also had chronic hypertension complicating pregnancy or gestational hypertension were classified as "pre-eclampsia or eclampsia superimposed on pre-existing hypertension." Women who met the definitions of any of the above hypertensive disorders of pregnancy were classified as "any hypertensive disorder in pregnancy."

We used Flash Code software (version 2007 Q4, Medical Coding and Compliance Solutions (MCCS), LLC; the software division of PMIC, Turlock, CA) to search for and select the desired ICD-9 codes.

Covariates

Covariates included a diagnosis of gestational diabetes (648.8x) or a diagnosis of pre-existing diabetes complicating a pregnancy (648.0x) during the 40 week pregnancy plus the two weeks after delivery. We identified multiple pregnancy using any ICD-9 code that referred to a pregnancy with more than one fetus. Type of bariatric surgery was assessed with common procedural terminology codes for surgery (see appendix A on bmj.com). We also included variables to represent the seven individual BlueCross BlueShield insurance plans (regions) as covariates.

Statistical methods

We used descriptive statistics to compare the clinical characteristics of women who delivered before and after surgery. We used Student's *t* tests for continuous variables and χ^2 tests for categorical variables. We calculated the proportion of women with each of the hypertensive disorders in the two groups and tested for differences between groups using Fisher's exact test. We used logistic regression to calculate the odds ratio and confidence intervals for each of the outcomes in unadjusted models and then in models adjusted for maternal age at delivery, multiple pregnancy, type of bariatric surgical procedure, pre-existing diabetes complicating pregnancy, and insurance plan.

We performed a subgroup analysis in 17 women who had deliveries both before and after surgery to compare the proportions of hypertensive disorders in pregnancy.

We conducted two additional analyses to evaluate for the possibility of selection bias. In addition to the covariates described above, we assessed the distribution, by group, of several conditions less likely to be affected by bariatric surgery or obesity. We also calculated a "risk of obesity score" in the year of bariatric surgery and the year of delivery to further evaluate selection bias at the time of surgery and delivery. These additional analyses are in appendix C on bmj.com.

P values less than 0.05 were considered significant. Statistical analyses were performed with SAS statistical software, version 9.1 (SAS, Cary, NC).

Fig 1 | Study flow for selection of study sample

RESULTS

We identified 936 women with codes for both bariatric surgery and inpatient point of service for a delivery (fig 1). Of these, we excluded 18 women with delivery dates we considered too close to the surgery date, either less than 280 days after surgery or less than 31 days before surgery. We excluded four women who did not meet the age requirement of 16-45 and 329 women who had incomplete insurance coverage during pregnancy. This yielded a final sample of 585 women, 269 who delivered before surgery and 316 who delivered after surgery.

The table shows the characteristics of women with deliveries before or after surgery. Women who delivered before surgery were younger at the time of delivery (mean age 31.3 *v* 32.5, P<0.002) but had more complicated pregnancies, with higher rates of pre-existing diabetes (23.4% *v* 12.3%, P<0.001) and gestational diabetes (25.7% *v* 13.0%, P<0.001). Rates of multiple pregnancy were similar between the two groups. More than half of the sample was from a Midwestern insurance plan.

The mean time from delivery to surgery was 17. 9 months (range 1.6-46.4 months), and the mean time from surgery to delivery was 23.6 months (range 9.3-53.3 months). Most women in each group underwent gastric bypass surgery (73.6% (198) in those who delivered before surgery and 88.3% (279) in those who delivered after; total 81.5% (477)). Women who delivered before surgery were more likely to have adjustable gastric banding (13.0% *v* 1.3%) (table).

Hypertensive disorders in pregnancy

Almost 15% of women who delivered before surgery group had pre-eclampsia or eclampsia compared with about 3% of those who delivered after surgery (P<0.001) (table). Mild pre-eclampsia was the most common diagnosis and was less common among the deliveries after surgery than the deliveries before surgery (2.0% *v* 9.0%). There were also lower rates of both severe pre-eclampsia and eclampsia in the deliveries after surgery. Rates of gestational hypertension (13.0% *v* 2.5%, P<0.001) and chronic hypertension complicating pregnancy (13.8% *v* 5.4%, P<0.001) were higher in the women who delivered before surgery. Almost 12% of women who delivered before surgery had pre-eclampsia or eclampsia superimposed on pre-existing hypertension compared with only 1% of women who delivered after surgery (P<0.001) (table).

We conducted multivariate logistic regression to create models adjusted for age at delivery, multiple pregnancy, type of bariatric surgical procedure, pre-existing diabetes, and insurance plan (fig 2). Compared with women who delivered before surgery, women who delivered after surgery had substantially lower rates of pre-eclampsia and eclampsia (odds ratio 0.20, confidence interval 0.09 to 0.44), chronic hypertension complicating pregnancy (0.39, 0.20 to 0.74), and gestational hypertension (0.16, 0.07 to 0.37) (fig 2). There were also lower rates of pre-eclampsia or eclampsia superimposed on pre-existing hypertension in the

Characteristics of women and complications of pregnancy associated with delivery before or after bariatric surgery. Figures are numbers (percentages) unless stated otherwise

Characteristic	Total (n=585)	Before surgery (n=269)	After surgery (n= 316)	P value
Mean (SD) age at delivery (years)	31.9 (4.7)	31.3 (4.4)	32.5 (4.9)	<0.002*
Mean (SD) age at surgery (years)	31.5 (4.8)	32.8 (4.4)	30.5 (4.9)	<0.001*
Mean (SD) time between surgery and delivery (months)	21.0 (9.7)	17.9 (9.1)	23.6 (9.5)	<0.001*
Type of surgery:				
Gastric bypass	477 (81.5)	198 (73.6)	279 (88.3)	<0.001†
Adjustable gastric banding	39 (6.7)	35 (13.0)	4 (1.3)	
Other‡	69 (11.8)	36 (13.4)	33 (10.4)	
Hypertensive disorders in pregnancy:				
Pre-eclampsia or eclampsia	47 (8.0)	39 (14.5)	8 (2.5)	<0.001§
Mild pre-eclampsia	29 (5.0)	23 (8.6)	6 (1.9)	<0.001§
Severe pre-eclampsia	15 (2.6)	13 (4.8)	2 (0.6)	
Eclampsia	3 (0.5)	3 (1.1)	0 (0.0)	
Chronic hypertension complicating pregnancy	54 (9.2)	37 (13.8)	17 (5.4)	<0.001§
Gestational hypertension	43 (7.4)	35 (13.0)	8 (2.5)	<0.001§
Pre-eclampsia or eclampsia superimposed on hypertension	35 (6.0)	31 (11.5)	4 (1.3)	<0.001§
Any hypertensive disorder in pregnancy	115 (19.7)	84 (31.2)	31 (9.8)	<0.001§
Other pregnancy conditions:				
Gestational diabetes mellitus	110 (18.8)	69 (25.7)	41 (13.0)	<0.001†
Multiple pregnancy	33 (5.6)	14 (5.2)	19 (6.0)	0.722†
Pre-existing diabetes complicating pregnancy	102 (17.4)	63 (23.4)	39 (12.3)	<0.001†

*Student's *t* test.
†χ^2 test.
‡Includes vertical banding, biliopancreatic diversion, gastric resection, unknown, other.
§Fisher's exact test.

women who delivered after surgery (0.13, 0.04 to 0.38). Overall, women who delivered after surgery had significantly reduced rates of any hypertensive disorder in pregnancy (0.25, 0.15 to 0.40).

Women with deliveries both before and after surgery

In the years studied (2002-6), 17 women had deliveries both before and after surgery. Because we did not require continuous insurance coverage for this subgroup analysis, six of the 17 women in this analysis were not included in the main analysis of 585 women. Seven were included in the before surgery group in the main analyses of 585 women and four were in the after surgery group, based on the delivery closest to surgery. In this subgroup analysis, most women did not have any claims for hypertension in either pregnancy. Five women had a claim for hypertension disorder in pregnancy during their pregnancy before surgery but did not have a claim during their pregnancy after surgery. One woman had a claim for hypertension disorder in pregnancy after surgery but not in her pregnancy before surgery. Results from the subgroup analysis were consistent with the findings from the main analyses.

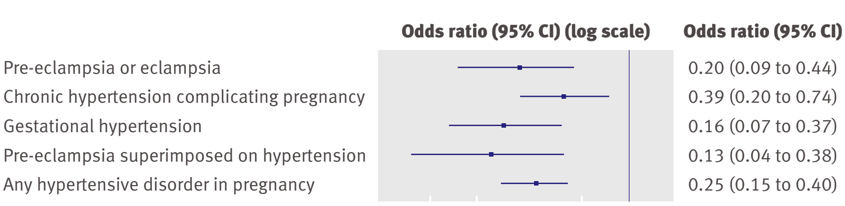

Fig 2 | Adjusted odds of hypertensive disorders in pregnancy in women who delivered after surgery compared with before surgery. Odds ratios adjusted for maternal age at delivery, multiple pregnancy, type of bariatric surgery, pre-existing diabetes complicating pregnancy, and insurance plan

DISCUSSION

In this insured population of women who had a pregnancy and delivery and underwent bariatric surgery during 2002-6, delivery after surgery was associated with substantially lower rates of all severities of hypertensive disorders in pregnancy. Women who delivered after surgery had a 75% lower odds of a diagnosis of a hypertensive disorder in pregnancy than women who had a delivery before surgery. Our findings support the use of bariatric surgery in women of childbearing age who meet eligibility criteria for surgery, either class III obesity or class II obesity with high risk comorbidities, to potentially decrease the rates of hypertensive disorders in pregnancy and associated complications.

Our study confirms the findings of other studies that described reductions in pre-eclampsia and gestational hypertension after bariatric surgery.[17] Few studies, however, have described the outcomes of chronic hypertension complicating a pregnancy and pre-eclampsia superimposed on chronic hypertension among women who have had bariatric surgery.[17 19 20] These outcomes are important because chronic hypertension is associated with adverse perinatal outcomes, including preterm birth and intrauterine growth restriction.[21] A considerable risk of chronic hypertension in pregnancy is its association with superimposed pre-eclampsia, which greatly increases perinatal morbidity and mortality.[21] In addition, research now suggests that chronic hypertension in pregnancy and pre-eclampsia increase the long term risk of chronic disease in the mother, including cardiovascular and renal disease.[22-24] Treating class II or III obesity with bariatric surgery before conception could reduce short term perinatal morbidity and longer term risks of chronic disease.[17 23]

Strengths and weaknesses

There are several strengths to this study. Firstly, we had access to a large claims database, which included four years of data from seven BlueCross BlueShield health insurance plans across the US. Thus, we believe our results are generalisable to a commercially insured population of women. Secondly, we compared rates of hypertensive disorders in pregnancy in deliveries before and after surgery. We confirmed the results of another recent study that used this study design in a population based sample from one hospital in Israel, which reported on a composite of hypertension disorders and other complications.[19] Other studies have attempted to identify appropriate comparison groups, either matching women with obese controls by BMI, or comparing with consecutive deliveries.[17] Obese women who choose to have bariatric surgery, however, might be different from obese women who do not, especially with respect to access to care and health behaviours,[25] which might not be measured. Clearly, comparisons with consecutive deliveries alone would introduce many confounders. Short of conducting a large randomised controlled trial of bariatric surgery to prevent hypertensive disorders in pregnancy, we believe our study to be of the best design.

While this was a large study, we recognise several limitations. Our administrative claims dataset lacked clinical information such as height and weight (to calculate BMI), blood pressure, and parity. Therefore, we based our outcome and covariate definitions on ICD-9 diagnosis codes rather than laboratory or clinical values. We adjusted for maternal age as the closest proxy for parity. Administrative data are susceptible to erroneously entered codes, incomplete and both over-coding and under-coding, which might have limited our ability to capture all diagnoses or outcomes. Several studies have evaluated the accuracy of ICD codes for diagnoses of hypertension in pregnancy.[26-30] One study used hospital discharge data (that is, inpatient codes only) from a single university hospital to evaluate the accuracy of pre-eclampsia codes compared with the diagnostic criteria from the American College of Obstetricians and Gynecologists. Only 54% of patients with any ICD-9 code for pre-eclampsia met these clinical criteria, probably representing over-coding, but almost 90% of patients with a code for severe pre-eclampsia accurately met these criteria.[27] In another validity study that used hospital discharge data, 74% of patients with any ICD-9 code for chronic hypertension had documentation of a diagnosis of hypertension in the discharge abstract,[30] and results were similar for gestational hypertension in another study.[28] Because we included claims from the entire pregnancy plus two weeks after delivery, including both inpatient and outpatient claims, we could capture the outcomes of mild pre-eclampsia and chronic and gestational hypertension managed in outpatients. We also anticipate that coding errors would be no different between women who had deliveries before or after surgery, thus limiting any introduced study bias. A limitation of our claims dataset is that we were unable to link maternal with neonatal records to assess neonatal outcomes associated with hypertensive disorders in pregnancy or complications of bariatric surgery, such as neonatal vitamin K deficiency.[31]

Finally, the possibility of selection bias and confounding is an inherent limitation in observational studies. In particular, confounding by indication[32] could have occurred. For example, an obese woman with gestational hypertension might have been more likely to subsequently undergo bariatric surgery if she developed chronic hypertension after her pregnancy or had other comorbidities associated with obesity making her eligible for bariatric surgery. If this occurred, the number of diagnoses of hypertensive disorder in pregnancy in the women who delivered before surgery could be increased and bias our results. In additional analyses, we calculated a propensity score for risk of obesity and obesity related comorbidities for the year of bariatric surgery and the year of delivery in the two groups. We found no significant difference in median propensity scores in the year of surgery, indicating low likelihood of selection bias for surgery. The median score was significantly reduced in the women who delivered after surgery during the year of delivery, consistent with the main findings showing reduced rates of hypertensive disorders in pregnancy in women who had bariatric surgery (see table A in appendix C on bmj.com). Also, bariatric surgery itself might have had other unmeasured effects on the care of women who delivered after surgery, such as improving overall medical care and decreasing risk for pregnancy complications. Women in both groups, however, had the same health insurance and probably the same equal access to healthcare services. In addition, a recent study using this same dataset showed a reduction in medications for conditions expected to improve after bariatric surgery but no change in other medication classes for disorders less likely to be affected by surgery, such as thyroid or allergy prescriptions.[33] We also found similar distributions between the groups of the conditions less likely to be affected by surgery or obesity (see table B in appendix C on bmj.com).

Implications of findings

Our results have important clinical, public health, and policy implications. Obesity, especially extreme obesity, is associated with increased rates of several complications related to pregnancy, as well as increased use of healthcare resources during pregnancy.[4 10 34] Increasing evidence supports the safety and efficacy of bariatric surgery in women of reproductive age to improve fertility and perinatal outcomes.[17] The American College of

WHAT IS ALREADY KNOWN ON THIS TOPIC

Hypertensive disorders in pregnancy complicate 7% of all pregnancies in the US and are a common cause of perinatal morbidity and mortality

Obesity is associated with adverse perinatal outcomes including hypertensive disorders in pregnancy

Bariatric surgery, an effective weight loss intervention for women with class II obesity (BMI 35-40) with comorbidities or class III obesity (BMI ≥40), reduces many perinatal complications

WHAT THIS STUDY ADDS

In a large retrospective analysis of US women, bariatric surgery was associated with lower rates of all severities of hypertensive disorders in subsequent pregnancies

Obstetricians and Gynecologists recently published guidance for clinicians about the management of pregnancy after bariatric surgery.[35] Based on the consistent reduction in all diagnoses of hypertensive disorders in pregnancy, bariatric surgery could be considered in the preconception management of women of childbearing age who have a BMI ≥40 or ≥35 with comorbidities. These data also support insurance policies that cover and reduce barriers to bariatric surgery to improve pregnancy outcomes and reduce maternal and neonatal costs associated with higher risk pregnancies. Future research should address long term maternal and child health after pregnancies and deliveries after bariatric surgery in terms of weight management, nutritional status, and burden of long term chronic disease.

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Competing interests: All authors have completed the unified competing interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) (URL) and declare (1) no financial support for the submitted work from anyone other than their employer; (2) no financial relationships with commercial entities that might have an interest in the submitted work; (3) no spouses, partners, or children with relationships with commercial entities that might have an interest in the submitted work; and (4) no non-financial interests that may be relevant to the submitted work.
Ethical approval: The study was approved by the institutional review board of the Johns Hopkins University School of Medicine.
Data sharing: No additional data available.

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