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Risk factors and outcomes of uterine rupture before onset of labor vs. during labor: a multicenter study

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Abstract

Objectives: This study aims to reveal the distinctions between uterine rupture (UR) that occurs before onset of labor and during labor.

Methods: This multicenter study was conducted across three tertiary hospitals in South China involving obstetrical UR from January 2009 to April 2022. Cases were categorized into two groups based on the timing of UR: prelabor and labor.

Results: Among the cases of UR, 42 were classified in the prelabor group, and 27 in the labor group. The prelabor group had a higher prevalence of histories of myomectomies, ectopic pregnancy surgeries, congenital uterine anomalies, and prior URs. Among these ruptures, 45.2 % were located at cesarean section (CS) scars, compared to 81.5 % of cases during labor. Ruptures before onset of labor occurred across all gestational intervals, whereas those during labor, except one, occurred after 32 weeks. The median gestational age was 33 and 39 weeks in each group. Notably, prelabor cases demonstrated longer symptom-to-delivery intervals. Placenta percreta was more common in the prelabor group (16.7 vs. 3.7 % in the labor

group). Among labor-related cases, 16 of the 27 occurred during trial of labor after cesarean (TOLAC), and four were identified following vaginal birth after cesarean (VBAC).

Conclusions: URs differ by timing relative to labor. Ruptures before onset of labor more often resulted from scars other than CS and placenta percreta, occurring at earlier gestational weeks. This finding highlighted challenges in diagnosis and management. In contrast, ruptures during labor mostly occurred after 32 weeks and were strongly associated with TOLAC/VBAC.

Keywords: maternal-fetal outcomes; rupture site; rupture timing; scarred uterus; invasive placenta

Introduction

Rupture of the gravid uterus, involving all layers of the uterine wall, poses a significant threat to both mother and neonate. Over recent years, the prevalence of uterine rupture (UR) has increased, driven by changes in maternal demographics and rising cesarean section (CS) rates [1]. In 2020, the overall CS rate among Chinese primiparous women exceeded 40.0 % [2]. The incidence of UR varies significantly between scarred and unscarred uteri, with rates of 22 per 10,000 and 0.2 per 10,000 deliveries, respectively [3, 4]. However, UR remains elusive to diagnose, often being misinterpreted as other obstetric problems, such as placental abruption, threatened labor, or even as gastrointestinal disorders [5]. Misdiagnosis and delayed diagnosis are critical contributors to poor pregnancy outcomes [6]. While cases of UR during labor typically benefit from intensive monitoring that allows for timely identification, those occurring before onset of labor are more likely to be misdiagnosed or neglected due to less frequent surveillance [7]. Thus, this study aims to address the distinctions between UR before onset of labor and during labor, with the goal of improving early recognition and facilitating prompt intervention.

Materials and methods

The data was retrieved from three tertiary medical centers in Guangdong Province, South China, covering a total of 261,435 deliveries from January 2009 to April 2022. The

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involved centers were The Third Affiliated Hospital of Guangzhou Medical University, Shenzhen Guangming District People's Hospital, and Dongguan Maternal and Child Health Care Hospital. This study adhered to the Declaration of Helsinki and was approved by the Institutional Review Board [IRB (2024)-126]. We identified obstetrical UR cases by the first author reviewing maternal medical records. The cases were stratified into two groups based on the timing of uterine rupture: prelabor and labor. The labor group was defined as UR after the onset of regular uterine contractions with cervical dilation ≥ 1 cm, whereas cases before this stage were categorized as prelabor. Baseline characteristics, predisposing factors, perioperative conditions, and maternal-fetal outcomes were systematically documented.

Variables and definition

Scarred uteri can be categorized into CS-related and other types, depending on the origin of surgical intervention. For this study, either clinical or pathological diagnoses of placenta increta and percreta are considered under the umbrella term of PAS disorder. Static UR means a fully symptomless rupture without any prior noticeable signs, often get diagnosed in elective CS [8]. Grand multiparity refers to a woman who has had ≥ 3 births at ≥ 20 weeks. Pre-hospital UR refers to cases occurring before hospital admission. In such situations, limited resources, compared to those available after admission, restrict opportunities for timely surgical intervention. Preoperative duration was measured in hours from the onset of symptoms (e.g., abdominal pain) to the decision to operate. Uterine repair involved restoring structural integrity by repairing the rupture site rather than excising it. Partial excision was performed to remove the gravid uterus in uterine didelphys or a uterus with severe invasive placenta. Hysterectomy referred to the surgical removal of the gravid uterine corpus, with or without the cervix, during the peripartum period. According to the Chinese Expert Consensus, severe neonatal asphyxia was: 1-min Apgar score 0–3 or 5-min Apgar score 0–5, with umbilical cord artery pH < 7.0 . Perinatal death includes stillbirth and neonatal death.

Statistical analysis

The statistical analysis was performed using IBM SPSS 22.0 software. Categorical variables were analyzed with the chi-square test, while continuous variables were assessed using either the t-test for normally distributed data or the Kruskal–Wallis test for non-normally distributed data.

Numerical data were presented as mean \pm standard deviation for normally distributed variables, and as median (P25, P75) for non-normally distributed variables. Categorical data were expressed as numbers (percentages). A p-value < 0.05 was considered statistically significant.

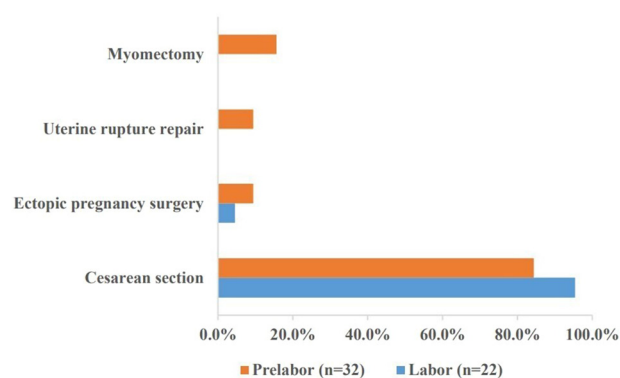
Results

The estimated prevalence of UR was 2.6 per 10,000 deliveries (69/261,435) over a span of 14 years. Among the cases of UR, 23 (33.3 %) resulted in perinatal death, 21 (30.4 %) involved preterm neonates, 20 (29.0 %) led to maternal hemorrhagic shock, and 11 (15.9 %) required hysterectomies. No maternal death was attributed to UR. Out of the 69 cases, 42 (60.9 %) occurred before onset of labor and 27 (39.1 %) occurred during labor. Maternal characteristics and pregnancy outcomes between the two groups were presented in Table 1. Compared to the labor group, the prelabor group had a higher proportion of nulliparous women and a relatively lower rate of scarred uteri. As shown in Figure 1, we calculated the percentages based on 32 cases with scarred uteri in the prelabor group and 22 cases in the labor group. CS was the predominant source of uterine scars in both groups; however, the prelabor group exhibited more diverse scar origins, with significant contributions from previous myomectomy, ectopic pregnancy surgery, and ruptured uterine repair. Three recurrent URs were noted: The first occurred after a rupture at term and resulted in intrauterine fetal death at 34⁺⁴ weeks. The second case had a history of uterine rupture at 29 weeks due to congenital didelphys uterus, this time terminated a pregnancy at 35⁺⁴ weeks with a live birth. The third case involved a cornual rupture at 33 weeks caused by placenta percreta, this time got diagnosed at 26 weeks for left upper quadrant abdominalgia. Fortunately, expectant management prolonged this pregnancy by 20 days, resulting in a delivery at 28⁺⁵ weeks of a 1,350 g neonate, with Apgar score of 3–7–8. Six women had placenta previa, with two complicated by placenta increta and three by placenta percreta. In terms of neonatal outcomes, the median gestational age (GA) at delivery was 33 weeks in the prelabor group and 39 weeks in the labor group. Figure 2 demonstrates the number of URs and rate of live birth at each gestational interval. UR before onset of labor could be observed across all intervals, while all labor-related URs, except one, occurred after 32 weeks of gestation. The live birth rate increased progressively with GA, rising from 50.0 % at 24–27 weeks to 90.9 % at 37–41 weeks. Among infants delivered at ≥ 32 weeks, 90.0 % (45/50) were live births. CS was the predominant mode of delivery in both groups, while the four vaginal deliveries were associated with vaginal birth after

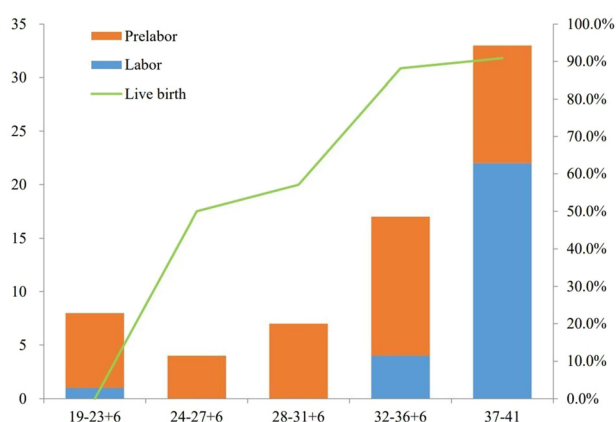
Table 1: Baseline characteristics and pregnancy outcomes in cases of UR occurred before onset of labor and during labor.

	Prelabor (n=42)	Labor (n=27)	p-Value
Maternal age, y	33 (26, 37)	31 (29, 35)	0.61
Pre-pregnancy BMI, kg/m ²	21.8 ± 3.6	21.9 ± 3.0	0.95
<i>In vitro</i> fertilization	4 (9.5)	2 (7.4)	0.76
Regular prenatal visit	26 (61.9)	21 (77.8)	0.17
Parity status			0.04
Nulliparous	9 (21.4)	1 (3.7)	
Multiparous	33 (78.6)	26 (96.3)	
Scarred uteri	32 (76.2)	22 (81.5)	0.60
Previous CS	27 (64.3)	21 (77.8)	0.24
Previous ectopic pregnancy surgery	3 (7.1)	1 (3.7)	0.55
Previous myomectomy	5 (11.9)	0 (0.0)	0.06
Previous UR	3 (7.1)	0 (0.0)	0.16
PAS history	2 (4.8)	0 (0.0)	0.25
Uterine malformations	5 (11.9)	1 (3.7)	0.24
Placenta previa	5 (11.9)	1 (3.7)	0.24
Baseline Hb, g/dL	11.4 ± 0.9	11.8 ± 0.9	0.18
GA at delivery, weeks	33.0 (27.0, 37.5)	39.0 (37.5, 40.1)	<0.001
Mode of delivery			0.01
Vaginal	0 (0.0)	4 (14.8)	
Cesarean	31 (100.0)	23 (85.2)	
Postpartum hemorrhage	18 (42.9)	12 (44.4)	0.90
Hemorrhagic shock	14 (33.3)	6 (22.2)	0.32
Inpatient days, d	9.4 ± 6.2	8.4 ± 4.9	0.49
Preterm birth	17 (60.7)	4 (17.4)	0.00
Perinatal death	17 (40.5)	6 (22.2)	0.12
Severe neonatal asphyxia	3 (10.7)	3 (13.0)	0.57
NICU admission	14 (50.0)	7 (30.4)	0.16

UR, uterine rupture; BMI, body mass index; CS, cesarean section; UR, uterine rupture; PAS, placenta accreta spectrum; Hb, haemoglobin; GA, gestational age; NICU, neonatal intensive care unit. Items with significant differences are shown in bold.

**Figure 1:** Origin of scars in ruptured scarred uterus in the prelabor and labor groups.

cesarean (VBAC). The prelabor group had a significantly higher rate of preterm birth compared to the labor group (60.7 vs. 17.4 %, $p=0.002$). The incidence of hemorrhagic

**Figure 2:** The number of URs and rate of live birth among women delivered at each gestational interval.

shock and perinatal death were also higher in the prelabor group, though with no significant difference.

As rupture onset, acute abdomen and cardiotocographic abnormalities (primarily bradycardia) were observed more often in the labor group, which also exhibited a higher rate of vaginal bleeding (70.4 vs. 26.2 %, $p<0.001$). Notably, URs before onset of labor were more likely to be diagnosed before hospital admission (59.5 vs. 7.4 %, $p=0.001$) and had a longer symptom-to-delivery interval compared to those during labor (6 vs. 4 h). The GA and hemoglobin (Hb) at admission was both significantly lower in the prelabor group (Table 2). In the labor group, 16 ruptures were detected during trial of labor after cesarean (TOLAC), and four happened right after VBAC, resulting in two hysterectomies and two stillbirths. Eight cases were associated with labor induction and two with oxytocin augmentation during TOLAC. A total of 41 ruptures were located at the CS scar of the anterior lower uterine segment, which were significantly more common in the labor group than in the prelabor group (81.5 vs. 45.2 %, $p=0.026$). Table 3 showed that ruptures occurring at the CS scar were associated with better outcomes compared to those at other sites, with a later delivery week and less estimated blood loss. In Table 2, one-third of URs before onset of labor correlated with abnormally invasive placenta, with 11 of the 14 cases occurring before 32 weeks of gestation. All five partial excisions were performed on women with placenta increta, two of whom had concomitant uterine didelphys. Estimated blood loss and the need for RBC transfusion were both higher in the prelabor group.

Discussion

Obstetrical UR is a rare and severe complication of pregnancy, encompassing a heterogeneous group of conditions.

Table 2: Clinical presentation in cases of UR occurred before onset of labor and during labor.

	Prelabor (n=42)	Labor (n=27)	p-Value
Rupture symptoms			
Abdominalgia	34 (81.0)	26 (96.3)	0.07
Vaginal bleeding	11 (26.2)	19 (70.4)	<0.001
Abnormal FHR	16 (38.1)	13 (48.1)	0.41
Unstable vital signs	8 (19.0)	4 (14.8)	0.65
Pre-hospital diagnosis	25 (59.5)	2 (7.4)	0.00
Preoperative duration, h	6.0 (3.8, 14.3)	4.0 (2.0, 6.0)	0.05
Admission GA, weeks	33.1 (26.8, 37.3)	39.0 (37.5, 39.6)	0.00
Admission Hb, g/dL	10.5 (8.4, 11.9)	11.9 (10.6, 12.3)	0.02
Underwent TOLAC	0 (0.0)	20 (74.1)	<0.001
Induction or augmentation of labor	7 (16.7)	3 (11.1)	0.52
Rupture sites			0.03
Uterine horn	7 (16.7)	1 (3.7)	
Uterine fundus	6 (14.3)	1 (3.7)	
Uterine body	10 (23.8)	3 (11.1)	
Cesarean scar	19 (45.2)	22 (81.5)	
PAS disorder	14 (33.3)	3 (11.1)	0.04
Placenta percreta	7 (16.7)	1 (3.7)	0.10
Surgical procedure			0.40
Uterine repair	30 (71.4)	23 (85.2)	
Partial uterine resection	4 (9.5)	1 (3.7)	
Hysterectomy	8 (19.0)	3 (11.1)	
Estimated blood loss, mL	850 (475, 2,350)	400 (300, 1,100)	0.03
RBC transfusion, U	4.9 ± 7.8	2.8 ± 3.6	0.13
RBC transfusion ≥4U	18 (42.9)	9 (33.3)	0.43
Postoperative Hb, g/dL	8.9 ± 1.6	8.5 ± 1.6	0.30

FHR, fetal heart rate; GA, gestational age; Hb, haemoglobin; TOLAC, trial of labor after cesarean; RBC, red blood cell. Items with significant differences are shown in bold.

Few studies have differentiated UR between prelabor and labor for the lack of a consistent definition. A study [4] defined ≥4 cm of cervical dilatation as UR during labor, whereas we adopted a more conservative criterion of ≥1 cm, as it marked the initiation of labor monitoring. As reported in previous studies, UR after the start of labor was generally more common than that before onset of labor (1.1 vs. 0.1 per 10,000 deliveries) [7, 9]. However, the proportion of URs before onset of labor in our dataset reached 60.9 %. This reverse pattern can be attributed to two major factors. First,

referral bias: half of the cases were collected from an Obstetrics Critical Care Center in South China, where complex and severe cases (mostly prelabor) were referred for advanced treatment. Second, the small sample size may not adequately represent real-world prevalence.

It's well known that scarred uterus was the most common risk factor for UR [10]. This study included 48 with CS scars and 11 with other types of scars (five myomectomies, four ectopic pregnancy surgeries, three rupture histories, and two PAS histories). Among the 69 ruptures, 59.4 % were located at the cesarean scar of the anterior lower uterine segment, consistent with a recent report [11]. URs before onset of labor more frequently occurred at unusual sites, such as the cornual region, fundus, and uterine body, which were associated with significantly worse outcomes [4]. This study found three cases of cornual rupture in women who had previously undergone laparoscopic surgery for ectopic pregnancy. Minimally invasive surgery and the use of energy devices increase the potential damage to the uterine myometrium. Cornual rupture occurred at the earliest GA compared to other sites and was associated with a higher estimated blood loss (Table 3). Women with a history myomectomy or UR usually experienced ruptures before onset of labor, consistent with previous literature [4]. Compared with abdominal myomectomy, the laparoscopic approach may increase the risk of UR in a subsequent pregnancy. Gil et al. reported a 0.43 % incidence of UR among pregnant women with previous myomectomy, with ruptures after laparoscopic myomectomy being 2.5 times more common than those after laparotomy [12]. To date, longitudinal studies remain insufficient to assess the impact of different surgical techniques and interventions on UR prevention.

PAS disorder was associated with an increased risk of UR before onset of labor and was often observed in pregnancies remote from term. We identified nine cases of placenta increta and eight of placenta percreta. The number of PAS-related ruptures in our data was significantly higher than in other reports, as one institution served as a PAS referral center. Over the past two decades, the incidence of PAS disorders has increased tenfold [13]. Prenatal B-ultrasound remains the preferred diagnostic tool for detecting

Table 3: Maternal and perinatal outcomes following uterine rupture at four anatomical sites.

	Cornua (n=8)	Fundus (n=7)	Body (n=13)	CS scar (n=41)
GA at delivery, weeks	27.2 ± 5.8 ^a	31.8 ± 6.1 ^b	31.4 ± 5.0 ^c	36.6 ± 5.2 ^{a,b,c}
Estimated blood loss, mL	1,800.0 ± 1,019.8	2,485.7 ± 1,532.4	2,367.3 ± 2,372.8	1,112.2 ± 1,862.7
Hemorrhagic shock	4 (50.0)	4 (57.1)	4 (30.8)	8 (19.5)
Hysterectomy	1 (12.5)	2 (28.6)	3 (23.1)	5 (12.2)
Perinatal death	4 (50.0)	3 (42.9)	5 (38.5)	11 (26.8)

GA, gestational age; CS, cesarean section. ^aRepresents p<0.001, ^brepresents p= 0.03, ^crepresents p=0.00.

PAS disorders, with magnetic resonance imaging serving as an additional aid when the maternal condition is stable [14]. A primigravida at 23 weeks was brought to emergency with acute abdomen, and an ultrasound examination reported fluid accumulation in the pelvis. As hemoglobin declined from 8.5 to 5.7 g/dL, a prompt laparotomy was performed. Cornual rupture and placenta percreta were identified, but no image of invasive placenta was detected before the operation. It is noteworthy that the woman had undergone two surgeries in the right tubo-uterine angle for ectopic pregnancy. Another primigravida who conceived via embryo transfer technology, presented with right lower abdominal dull pain and oligohydramnios at 35⁺ weeks. Magnetic resonance image revealed extensive placenta percreta in the left anterior uterine wall. Following trans-abdominal access, obstetricians noticed a 1.0 cm breach at the uterus's left anterior wall [15]. A large population-based study in China revealed that placenta percreta was the strongest risk for UR at 28–33 weeks, especially in those without a CS scar [16]. In our study, 57.9 % of URs before 32 weeks were associated with PAS. All five partial uterine resections were performed on patients with PAS, and 7 out of 11 total hysterectomies were related to PAS. Further investigations are needed into prenatal screening to prevent PAS-related UR.

Besides ruptures associated with scarred uteri, 15 cases were identified in uteri that were intact and unscarred. Relevant backgrounds included PAS disorders, congenital uterine anomalies, grand multiparity, a history of conservatively managed PAS, pelvic inflammatory disease, previous hysteroscopic procedures or multiple abortions, and the inappropriate use of oxytocin or prostaglandin analogues. Six cases of congenital uterine anomalies were confirmed, including three didelphys uteri, two septate uteri, and one bicornuate uterus. In such cases, uncoordinated uterine contractions may result from structural defects and aberrant distribution of oxytocin receptors. Prolonged exposure to oxytocin or prostaglandin analogues may increase risk of UR, particularly in cases of obstructed labor or with excessive dosages [17]. Eight ruptures in the second and third trimesters were linked to labor induction, including four with rivanol, one with oxytocin following two cesarean sections at term, and three with unknown dosages. Improper medication or lax indications may be triggers of UR. None of them received prenatal examinations, and they presented with severe consequences from 19 to 34 weeks. Ruptures in unscarred uteri are extremely rare but prone to extensive uterine injury and catastrophic outcomes [18, 19]. According to a large-scale study by Al-Zirqi et al., unscarred URs showed a 2.6-fold higher risk of peripartum hysterectomy than scarred uteri [9]. Our study noted that women with unscarred uteri had 26.7 % of

hysterectomies and 46.7 % of perinatal mortalities, both higher than the rates in women with scarred uteri (13.0 and 29.6 %, respectively).

According to a multi-country prospective study in Europe, URs before onset of labor accounted for 57.7 % of atypical cases (unscarred, preterm or prelabor) [4]. Abdominal pain is a common clinical sign of UR [20]. Atypical abdominal pain may exist under some rare circumstance [21]. High frequency of vaginal bleeding in the labor group can be explained by labor progress. No correlation was found between the amount of blood loss and the severity of rupture. In some cases, severe intra-abdominal hemorrhage may occur without vaginal bleeding, except when cervical lacerations were present. Abnormal cardiotocographic findings were slightly less common in the prelabor group compared to the labor group. However, this comparison showed limited, as more women in the prelabor group had not yet reached the gestational age required for continuous electronic fetal heart rate monitoring. URs in the second trimester resulted in 50.0 % hysterectomies, whereas this rate decreased to 8.8 % in the third trimester. Hypovolemic shock remains the primary cause of maternal death secondary to UR [22]. Surgical removal of the uterus is the most effective approach to control persistent intra-peritoneal hemorrhage when other interventions fail. The likelihood of live birth was significantly higher in deliveries after 32 weeks. Fetal mortality can be minimized if an immediate CS is performed, with delivery completed within 20 minutes. In contrast, the risk of perinatal death increases 16-fold if delivery is delayed beyond 30 min (OR, 16.7; 95 % CI, 6.4–43.5) [23]. Placental separation and fetal extrusion were the main causes of perinatal death and severe asphyxia [24]. Currently, no reliable methods exist to predict UR. Some studies suggested that a lower uterine segment thickness of ≥ 2.3 mm near-term, assessed by ultrasound, may safely allow TOLAC [25]. However, this approach has shown poor specificity and remains unreliable for clinical application [26]. Further exploration of novel predictive markers for UR is warranted to improve early detection and intervention.

Conclusions

This study showed the distinct features and outcomes of UR before and during labor. UR before onset of labor was more likely to be associated with scarred uteri not originating from CS, and those with PAS disorder. They were characterized by early onset and relatively longer symptom-to-delivery intervals, resulting in higher maternal-fetal morbidity and fetal mortality. URs during labor mostly occurred in the CS scar after 32 weeks and were generally associated with favorable

outcomes. These disparities emphasized the importance of heightened awareness and diagnostic vigilance in managing suspected UR before onset of labor.

Research ethics: The study was approved by the Institutional Review Board of the Third Affiliated Hospital of Guangzhou Medical University on June 23, 2024. Approval ID: IRB (2024)-126. It was conducted in accordance with the Declaration of Helsinki.

Informed consent: Not applicable.

Author contributions: F He, QW Nie: Project development. Qw Nie, Sj Luo, L Wang: Data collection or management. Qw Nie, Bj Chen: Data analysis. Qw Nie, Sj Luo and Bj Chen: Manuscript writing and revising. All authors have accepted responsibility for the entire content of this manuscript and approved its submission.

Use of Large Language Models, AI and Machine Learning

Tools: We used ChatGPT for improving language quality in the later revision. The LLM was not involved in the research design, data collection, or the drafting of the original manuscript.

Conflict of interest: The authors state no conflict of interest.

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Data availability: The raw data can be obtained on request from the corresponding author.

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