

# BMJ Open How far is too far? A nationwide cross-sectional study for establishing optimal hospital access time for Korean pregnant women

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## ABSTRACT

**Objectives** Access to a delivery unit is a major factor in determining maternal morbidity and mortality. However, there is little information about the optimal access time to a delivery unit. This study aimed to establish the optimal hospital access time (OHAT) for pregnant women in South Korea.

**Design** Nationwide cross-sectional study.

**Setting** We used the National Health Insurance System database of South Korea.

**Participants** We analysed the data of 371 341 women who had experienced pregnancy in 2013.

**Primary and secondary outcome measures** Access time to hospital was defined as the time required to travel from the patient's home to the delivery unit. The incidence of obstetric complications was plotted against the access time to hospital. Change-point analysis was performed to identify the OHAT by determining a point wherein the incidence of obstetric complications changed significantly.

As a final step, the risk of obstetric complications was compared by type among pregnant women who lived within the OHAT against those who lived outside the OHAT.

**Results** The OHAT associated with each adverse pregnancy outcomes were as follows: inadequate prenatal care, 41–50 min; preeclampsia, 51–60 min; placental abruption, 51–60 min; preterm delivery, 31–40 min; postpartum transfusion, 31–40 min; uterine artery embolisation, 31–40 min; admission to intensive care unit, 31–40 min; and caesarean hysterectomy, 31–40 min. Pregnant women who lived outside the OHAT had significantly higher risk for obstetric complications than those who lived within the OHAT.

**Conclusions** Our results showed that the OHAT for each obstetric complication ranged between 31 and 60 min. The Korean government should take the OHAT under consideration when establishing interventions for pregnant women who live outside OHAT to reduce maternal morbidity and mortality.

## INTRODUCTION

Adequate access to a healthcare system is an important issue in public health. The American Institute of Medicine defined it as ‘the timely use of personal health services to achieve the best possible health outcomes’

## Strengths and limitations of this study

- We used large linked database representing all pregnancies in South Korea to investigate the association between geographical access time and adverse maternal outcome.
- The access time to hospital was calculated by using the road network analysis by a geographic information system with big national health data, which lends further credibility to its results.
- We confirmed that long travel time from home to hospital could affect the health of mothers and babies.
- Limitations include some essential health outcomes of neonates such as neonatal weight, congenital anomalies, or infant mortality could not be examined due to restricted access to relevant data

and classified three types of barriers for timely access: structural, financial and personal.<sup>1</sup> Distance to healthcare services is one of the most important out of all structural barriers. For example, rural parturient women who have to travel to access maternity services have increased rates of adverse outcomes and newborns have increased numbers of Neonatal Intensive Care Unit (NICU) 2 and 3 care days in developed country.<sup>2</sup>

Although the number of counties in which more than 10% of women lived outside the 1 hour zone from obstetric institution, the geographical accessibility has gained little attention even in well-developed countries.<sup>3</sup> Relatively few studies have reported that longer distance increases the risk of adverse pregnancy outcomes even in developed countries.<sup>3 4</sup> However, the optimal access time to delivery unit that reduces adverse obstetric outcomes has not been evaluated, although it is of paramount importance in public health policy on maternal care.

According to the amendment of the Maternal and Child Health Law, the foundation for the establishment of the Center for Maternal Maternity Care was established in 2018. Perinatal healthcare networks (regional-local maternity medical center—obstetric care underserved areas (OCUA) centre) are established. But mothers choose hospitals according to their free will and give birth everywhere. The 17 high-level local administrative territories of the South Korea shall consist of one Seoul metropolitan city, six metropolitan cities, one self-governing city and nine provinces. There are 250 low-level local governmental areas in total. In recent decades, there has been a trend of closing small-size obstetric units in South Korea. As a result, 38 regions among 250 administrative districts are designated as ‘OCUA’ where there are no obstetrics and gynaecology clinics or hospitals providing prenatal care and delivery services.<sup>5</sup> This development is coincident with worldwide regionalisation of health services that has resulted in challenges to recruiting healthcare providers in rural areas.<sup>6,7</sup> The government defines OCUA as regions where more than 30% of residents lack access to delivery services within a 60 min drive and where obstetric care utilisation rate is less than 30% in 60 min (Timely Relevance Index rate). However, no previous study has provided evidence that sufficiently supports the 60 min benchmark. In view of public health policy, identifying the optimal access time to delivery unit is a critical issue. If the optimal geographical access time is appropriately established, maternal health policy may focus on pregnant women who live outside the optimal hospital access time (OHAT) to reduce adverse pregnancy outcomes that result from structural barriers to healthcare system. For this purpose, we undertook this study to establish the OHAT in South Korea.

## METHODS

### Data source and study design

In this nationwide cross-sectional study, we used National Health Insurance System (NHIS) database of South Korea. NHIS is the only healthcare insurer in South Korea providing health insurance to all Koreans. It has been accumulating medical records and personal information based on medical claim data submitted from healthcare providers. For this reason, we were able to analyse all of South Korea’s labour data. Using the NHIS database, we selected of 371 341 pregnant women who had experienced pregnancy (including delivery and pregnancy with abortive outcome) from 1 January 2013 to 31 December 2013. Then, we connected each person’s claims data and personal geographical information from NHIS database and National Spatial Data Infrastructure Portal. In order to evaluate prenatal and postpartum care, we used the data before and after event year (2012 and 2014).

### Definition of access time to hospital

We extracted the information on each woman’s address and location of the delivery unit where the woman’s

delivery took place. ‘Access time to hospital’ was defined as the travel time by car from the pregnant women’s residence to a department of obstetrics and gynaecology where they gave birth. Travel time by car was calculated with a geographic information system (GIS) package including a national drive time matrix, which took into account the Ministry of Land, Infrastructure and Transport network analysis system. The Ministry of Land, Transport and Maritime Affairs has developed a programme (National Spatial Data Infrastructure Portal: <http://www.nsd.go.kr/lxmap/index.do>) for urban development projects using GIS. This GIS programme helps to efficiently perform the national land space planning work by combining land information such as land management, construction administration and land-use regulation with GIS. In our study, we measured the distance and driving time with the national health insurance claim data using GIS developed by The Ministry of Land, Transport and Maritime Affairs.

### Definitions of obstetric complications

Obstetric complications included: preeclampsia, placental abruption, preterm delivery, postpartum transfusion, uterine artery embolisation, admission to intensive care unit (ICU) and caesarean hysterectomy, all of which are known to be increased in areas with low accessibility to medical care.<sup>8–13</sup> These obstetric complications were defined based on the International Classification of Diseases-10 and electronic data interchange code (table 1). Finally, inadequate prenatal care was defined as number of hospital visits during pregnancy of less than four times, adopted from the Kessner Index.<sup>14</sup>

### Definition of OHAT

Predicted incidence rates of obstetric complications per 1000 pregnant women were calculated by multiple regression model adjusted for maternal age, socioeconomic status, Charlson Comorbidity Index, urbanisation and size of the hospital. Charlson Comorbidity Index was adopted to reflect the effect of individual health status.<sup>15–17</sup> The predicted incidence rates per 1000 pregnant women for overall and each obstetric complication were plotted against access time to hospital at 10 min intervals to determine the OHAT. Change-point analysis (CPA) defined OHAT as a point where the incidence of obstetric complications significantly changed. The procedure for performing a CPA iteratively uses a combination of cumulative sum charts (CUSUM) and bootstrapping to detect the changes. A bootstrap is performed by: generate a bootstrap sample of data 10 min’ units and based on the bootstrap sample, calculate the bootstrap CUSUM, denoted 10 min, 20, ..., 350 min. And then calculate the maximum, minimum and difference of the bootstrap CUSUM. Then, the confidence level (CL) is required that a significant change has been detected. If there are 995 which had significant change, out of 1000 bootstraps, this gives a CL of: (confidence level=100\*995/100 %=99.5%).

**Table 1** The definition of abortion, delivery and obstetric complications

Variables	ICD-10 code and EDI code
Abortion	O00-O08(O00-O089)
Delivery	
Caesarean section	O82 (O820–O829), O842
Vaginal delivery	O80 (O800–O809), O81 (O810–O815), O83 (O830–O839), O840, O841
Obstetric complications	
Preeclampsia	O14 (O140–O149)
Eclampsia	O15 (O150–O159)
Placental abruption	O45 (O450–O459)
Preterm delivery	O601
Postpartum transfusion	X1001, X1002, X2011, X2012, X2021, X2022, X2031, X2032, X2131, X2132, X2091, X2092, X2515, X2512
Admission to ICU	AJ110, AJ210, AJ120, AJ220, AJ130, AJ230, AJ140, AJ240, AJ150, AJ250, AJ100, AJ200, AJ300, AJ180, AJ280, AJ380
Uterine artery embolisation	M6644
Caesarean hysterectomy	R4507, R4508, R4509, R4510, R5001, R5002

EDI, electronic data interchange; ICD, International Classification of Diseases; ICU, intensive care unit.

### Statistical analysis

All analyses were conducted with SAS, V.10.2 (SAS Institute). All statistical tests were two sided and a  $p < 0.05$  was considered statistically significant. In addition, we used CPA tool developed by Taylor<sup>18 19</sup> to get the OHAT. CPA tool is a method that allows to determine whether a change has taken place in time series dataset; it is effective at detecting non-periodic events from data.<sup>20</sup> Furthermore, it better characterises the changes detected by providing CLs and CIs. Finally, we used multiple logistic regression analysis to compare the risks of adverse obstetric outcomes between patients who live within the OHAT and those live outside the OHAT.

### RESULTS

Data on 371 341 women were included in the analysis (table 2).

Level of income was categorised as high level (upper 25% of premium), intermediate level (middle 50%) and low level (lower 25%) based on their national health insurance premium.

Figure 1 shows the distribution map of the number of pregnant women according to 250 municipalities. The number of deliveries was divided into five categories ( $\leq 308$ , 309–1305, 1306–2299, 2300–3743,  $> 3744$ ).

Figure 2 shows the distribution of the number of pregnant women according to access time to hospital; 84% of pregnant women resided within 60 min from hospital; 92% within 120 min; 97% within 180 min.

Figure 3 demonstrates the predicted incidence rates per 1000 pregnant women and cumulative rates of all or each obstetric complication against access time to hospital (minutes). CPA estimated the OHAT for each adverse pregnancy outcome as follows:

- ▶ 41–50 min for inadequate prenatal care,
- ▶ 51–60 min for eclampsia or preeclampsia,
- ▶ 51–60 min for placental abruption,
- ▶ 31–40 min for preterm delivery,
- ▶ 31–40 min for postpartum transfusion,
- ▶ 31–40 min for uterine artery embolisation,
- ▶ 31–40 min for admission to ICU, and
- ▶ 31–40 min for caesarean hysterectomy (figure 3 and table 3).

Table 3 represents change-point (CP) time as outcome variability (CI) with confidence level (CL) as estimated by the CPA tool. Average CP time is 46 min on eight outcome indicators. For example, the incident cases per 1000 mothers for inadequate prenatal care tend to occur with significant meaningful change at 41–50 min of access time to hospital (100% CL). For each obstetric complication indicator, incident cases per 1000 mothers for preeclampsia or eclampsia (100% CL) and placental abruption (99% CL) tend to occur with significant meaningful change at 51–60 min of access time to hospital. And incident cases per 1000 mothers for preterm delivery (97% CL), postpartum transfusion (97% CL), uterine artery embolisation (97% CL), admission to ICU (97% CL) and caesarean hysterectomy (97% CL) tend to occur with significant meaningful change at 41–50 min of access time to hospital.

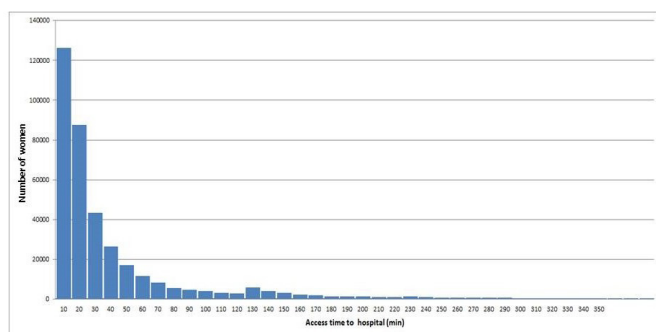
In logistic regression analysis, patients who live outside OHAT had significantly higher risk for obstetric complications than those who live within OHAT after adjusting confounding variables (table 4). Pregnant women who live outside OHAT (41–50 min) have a higher risk of inadequate prenatal care (adjusted OR (aOR) 1.17, 95% CI 1.06 to 1.28) than the women who live within 40 min of access time to hospital. Pregnant women who live outside

**Table 2** General characteristics

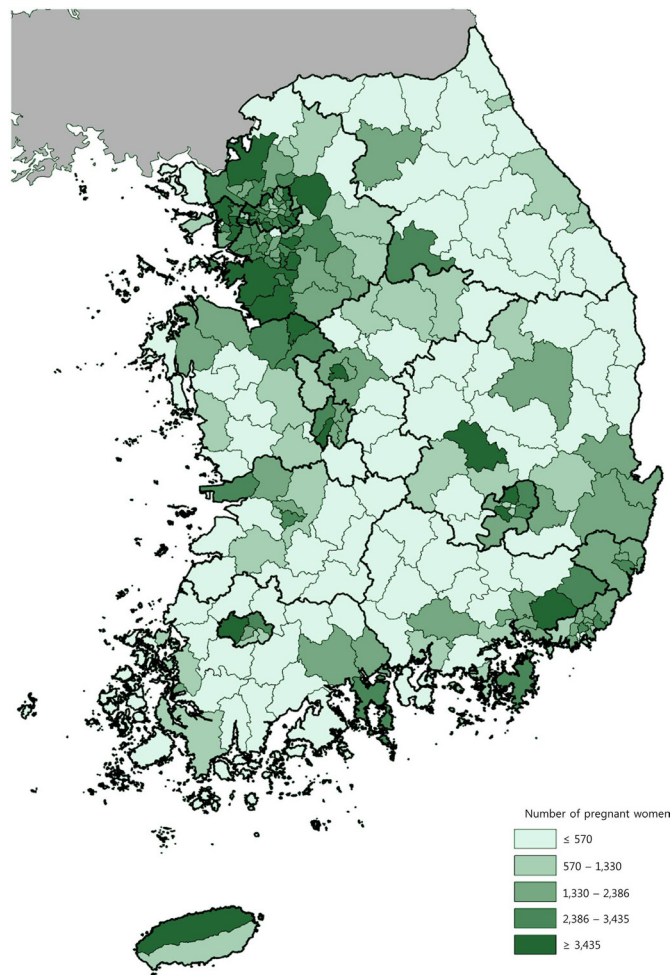
Variables	No (%) of women
Total	371 341 (100.0)
Age	
Mean±SD	31.5±4.19
Area*	
Metropolitan	238 416 (64.2)
City	109 415 (29.5)
Rural	23 510 (6.3)
Type of insurance	
NHI	369 179 (99.3)
MA	2162 (0.7)
Level of income	
High (upper 25%)	64 127 (17.26)
Medium (25%–75%)	247 612 (66.68)
Low (lower 25%)	59 602 (16.05)
Termination of pregnancy	
Abortion	13 254 (3.56)
Delivery	358 087 (96.43)
Result of childbirth	
Live birth	356 346 (95.96)
Stillbirth	1741 (0.46)
Subtotal	358 087 (96.43)
Type of delivery	
Caesarean section	125 761 (33.86)
Vaginal delivery	230 585 (62.09)
Subtotal	356 346 (95.96)

MA, Medical Aid; NHI, National Health Insurance.

OHAT (31–40 min) have higher risk of preterm delivery (OR 2.2, 95% CI 1.96 to 2.47), uterine artery embolisation (OR 1.54, 95% CI 1.05 to 1.83), admission to ICU (OR 1.42, 95% CI 1.02 to 1.98) and caesarean hysterectomy (OR 2.69, 95% CI 1.09 to 6.65) than the women who live within 30 min of access time to hospital. Pregnant women who live outside OHAT (51–60 min) have a higher risk of placental abruption (OR 3.23, 95% CI 1.57 to 6.64) and



**Figure 2** The number of pregnant women according to access time to hospital.



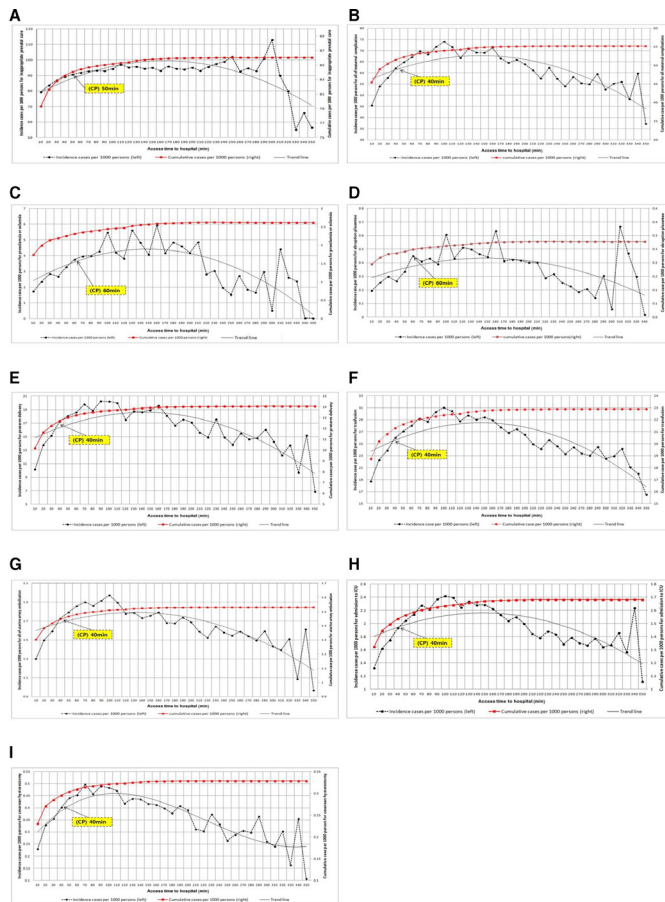
**Figure 1** The number of pregnant women according to low-level local governmental areas.

preeclampsia or eclampsia (OR 2.03, 95% CI 1.32 to 3.10) than the women who live within 50 min of access time to hospital.

## DISCUSSION

The OHAT for each adverse pregnancy outcome was ranged 30–60 min depending on the specific adverse outcome. In addition, pregnant women who live outside OHAT had 1.17 to 3.23 times higher risk of obstetric complications than those who live within OHAT.

The current study found that the CPs of inappropriate prenatal care and obstetric complications were within 60 min, in accordance to the result of previous studies. In addition, we also evaluated the significant CPs for each complication. The CPs of postpartum haemorrhage (transfusion, uterine artery embolisation, caesarean hysterectomy), preterm delivery and admission to ICU were 31–40 min, which was earlier than inadequate prenatal care, preeclampsia or placental abruption (41–60 min). This reflects the fact that the emergent diagnostic and therapeutic interventions are essentially needed within 60 min for reduction of these complications. In addition, the public resources might have to be more concentrated



**Figure 3** The predicted and cumulative incidence of obstetric complications and access time to hospital. CP, change point.

**Table 3** Change points (CPs) of inappropriate prenatal care and obstetric complications

Obstetric complications	Significant change point	
	CP time (CI)	CL
Inadequate prenatal care (Kissner Index* $\leq 4$ )	41 to 50 min	100%
Overall obstetric complication	31 to 40 min	100%
Preeclampsia or eclampsia	51 to 60 min	100%
Placental abruption	51 to 60 min	99%
Preterm delivery	31 to 40 min	99%
Postpartum transfusion	31 to 40 min	97%
Uterine artery embolisation	31 to 40 min	97%
Admission to ICU	31 to 40 min	97%
Caesarean hysterectomy	31 to 40 min	97%

\*Kessner Index is based on the total number of visits for prenatal cares during pregnancy. If they visited less than four times, it was evaluated as 'inadequate'.

CL, confidence level; ICU, intensive care unit.

to reduce these acute complications in women who reside far from hospitals.

This study also aimed to show an association between geographical accessibility and maternal outcomes in South Korea to establish and validate OHAT for OCUA. Pregnant women who lived outside the OHAT had significantly higher risk for obstetric complications than those who lived within the OHAT (aOR 1.17–3.23; 95% CI 1.02 to 6.65).

Long travel time from home to hospital could affect the health of mothers and babies. The Korean government recognises OCUA could be a serious public health concern. To address the disparities, the Korean government designated OCUA and support operation budgets for obstetric care facilities or equipment. Furthermore, the Korean government would like to establish the OHAT for OCUA regions. Efficient resource allocation is crucial even in equity policies run by government and thus evidence is needed to guide these policies.

According to definition of OCUA by government (2014), suboptimal hospital access is defined as travel time of 60 min or more although no previous studies examined the evidence behind the 60 min benchmark in South Korea. In order to develop policies on prenatal care and delivery services for underserved areas, consensus on what constitutes suboptimal hospital access time (in opposition to OHAT) is urgently needed.

Several studies reported that the amount of resources available are associated with geographical accessibility to neonatal and maternal care.<sup>21 22</sup> A shortage of obstetricians in rural areas has led to an increase in the rate of pregnancy-related complications and mortality and found a 9% increase was associated with the loss of local specialist obstetrical care.<sup>23</sup> Based on these results, the Korean government need to expand the installation of the perinatal centre and increase specialist obstetrical care in vulnerable areas and concentrated resources. Similar Japanese policies resulted in reduction of access time to hospital of about 28 min over the course of 4 years and resulted in the decrease of neonatal deaths.<sup>24</sup> The median travel time reduced from 66.9 min in 2002 to 39.1 min in 2006 and the mean neonatal mortality rate decreased from 1.72 to 1.33 over the same period. In addition, study authors recommended reduction of time needed for interfacility transportation to under 60 min and an increase of the number of obstetricians per 10 000 childbirths for country-wide reduction of adverse outcomes.

Following the establishment of OHAT, the Korean government should take initiatives to protect the health of pregnant women in OCUA in two ways. First, they should provide special services for pregnant women who have travel over 60 min to hospitals. Second, when planning new hospital for childbirth, a location where the highest number of prospective pregnant women could be served within the catchment area should be considered. The most significant strength of this study is that we used large linked database representing all pregnancies in South

**Table 4** OR for obstetric complications by travel time on multiple logistic regression analysis\*

Obstetric complications	Travel time	aOR (95% CI)	P value
Inadequate prenatal care	41–50 min (reference: ≤40 min)	1.17 (1.06 to 1.28)	0.001
Preeclampsia or eclampsia	51–60 min (reference: ≤50 min)	2.03 (1.32 to 3.10)	0.0011
Placental abruption	51–60 min (reference: ≤50 min)	3.23 (1.57 to 6.64)	0.0014
Preterm delivery	31–40 min (reference: ≤30 min)	2.2 (1.96 to 2.47)	<0.0001
Postpartum transfusion	31–40 min (reference: ≤30 min)	1.47 (1.22 to 1.67)	<0.0001
Uterine artery embolisation	31–40 min (reference: ≤30 min)	1.54 (1.05 to 1.83)	0.0093
Admission to ICU	31–40 min (reference: ≤30 min)	1.42 (1.02 to 1.98)	0.0383
Caesarean hysterectomy	31–40 min (reference: ≤30 min)	2.69 (1.09 to 6.65)	0.0316

\*Adjusted for age, socioeconomic status, Carlson Comorbidity Index, urbanisation and volume of the hospital.  
aOR, adjusted OR; ICU, intensive care unit.

Korea to investigate the association between geographical access time and adverse maternal outcome. The access time to hospital was calculated by using the road network analysis by GIS with big national health data, which lends further credibility to its results.

However, there are some limitations in this study. First, our study did not reflect the actual event location, that is, where contractions started; we used registered patient address rather than the location where labour started. Second, we adopted the Kessner Index<sup>15</sup> to define inadequate prenatal care, and considered the care to be 'inadequate' when there were fewer than four prenatal care visits. Therefore, we were only able to evaluate the quantity of visits and not the quality of care received. Third, some essential health outcomes of neonates such as neonatal weight, congenital anomalies or infant mortality could not be examined due to restricted access to relevant data.

In sum, the OHAT for each obstetric complications ranges between 31 and 60 min. Korean government should consider these OHATs when establishing health policies for pregnant women and should provide special interventions reducing areas of which access time to hospital exceed OHAT.

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**Competing interests** None declared.

**Patient consent for publication** Not required.

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**Data availability statement** All data relevant to the study are included in the article.

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