



Arterial Stiffness Assessment: A Comparative Study between Hypertensive and Normotensive Subjects at the Urgences Cardio Clinic in Dakar, Senegal

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Abstract

Introduction: Arterial stiffness is a major marker of vascular aging and an independent predictor of cardiovascular morbidity and mortality. Hypertension, highly prevalent in sub-Saharan Africa, plays a central role in the pathophysiology of arterial stiffness and target organ damage. However, data on arterial stiffness in West Africa, particularly in Senegal, remain scarce. This study aimed to assess arterial stiffness and compare pulse wave velocity between hypertensive and normotensive outpatients in Dakar. **Methods:** This was a cross-sectional, comparative, descriptive, and analytical study conducted at the Urgences Cardio Clinic in Dakar. Adult outpatients were consecutively included and divided into two groups according to blood pressure status (hypertensive versus normotensive). Sociodemographic and clinical data, as well as cardiovascular risk factors, were collected. Arterial stiffness was assessed using finger-to-toe pulse wave velocity (ftPWV) measured by photoplethysmography with the pOpmètre®. Global cardiovascular risk was estimated using the Framingham risk score. Statistical analysis was performed to identify factors associated with increased arterial stiffness. **Results:** Arterial stiffness was higher in hypertensive patients compared with normotensive subjects. Finger-to-toe pulse wave velocity increased significantly with age, highlighting a positive correlation between vascular aging and arterial stiffness. Elevated blood pressure, higher pulse pressure, and the accumulation of

cardiovascular risk factors were associated with higher ftPWV values. Moreover, patients with a higher global cardiovascular risk according to the Framingham score exhibited greater arterial stiffness. Multivariate analysis identified age, hypertensive status, and cardiovascular risk factor burden as the main determinants of increased arterial stiffness. **Conclusion:** Arterial stiffness is significantly greater in hypertensive subjects and is strongly influenced by age and cardiovascular risk factors in our population. Measurement of ftPWV using the pOpmètre®, a simple and non-invasive method, appears to be a relevant tool for the early detection of vascular aging in resource-limited settings. Its integration into hypertension management could improve cardiovascular risk stratification in sub-Saharan Africa.

Keywords

Arterial Stiffness, Pulse Wave Velocity, Hypertension, Cardiovascular Risk, pOpmètre, Senegal

1. Introduction

Cardiovascular diseases are the leading cause of mortality worldwide, and their burden is rising markedly in low- and middle-income countries, particularly in sub-Saharan Africa [1]. In this context, the identification of early markers of cardiovascular risk represents a major public health priority. Arterial stiffness, defined as the reduction in compliance and distensibility of large arteries, is now recognized as an independent marker of vascular aging and overall cardiovascular risk [2] [3].

Pulse wave velocity (PWV) is considered the non-invasive gold standard for the assessment of arterial stiffness. Numerous studies have demonstrated that increased PWV is independently associated with the occurrence of major cardiovascular events and mortality, regardless of traditional cardiovascular risk factors [3] [4]. From a pathophysiological perspective, hypertension and arterial stiffness have a bidirectional relationship: chronic elevation of blood pressure promotes vascular remodeling and stiffening of the arterial wall, while increased arterial stiffness leads to higher systolic blood pressure, increased pulse pressure, and greater left ventricular afterload, thereby contributing to target organ damage [2] [5].

Hypertension represents a major public health issue in sub-Saharan Africa, with high prevalence rates and frequently inadequate blood pressure control, resulting in substantial cardiovascular morbidity and mortality [1] [6]. However, data on arterial stiffness in West Africa, particularly in Senegal, remain scarce. The use of simplified devices such as the pOpmètre®, which measures finger-to-toe pulse wave velocity by photoplethysmography, provides a non-invasive, rapid, and practical alternative that is well suited to resource-limited settings [7].

Therefore, the objective of this study was to assess arterial stiffness and to compare finger-to-toe pulse wave velocity between hypertensive and normotensive outpatients in Dakar, Senegal, in order to identify factors associated with in-

creased arterial stiffness in our setting.

2. Methods

2.1. Study Design and Setting

This was an observational, analytical, and comparative cross-sectional study conducted at the Laboratory of Physiology and Functional Explorations of the Faculty of medicine, pharmacy and dentistry of UCAD and at the Urgences Cardio Clinic, in Dakar (Senegal).

2.2. Study Population

The study population consisted of adult patients attending outpatient consultations at the clinic during the study period. Participants were classified into two groups according to their blood pressure status: hypertensive subjects and normotensive subjects.

2.3. Inclusion Criteria

The following patients were included in the study:

- patients aged 18 years and older;
- patients who underwent blood pressure measurement and arterial stiffness assessment using the pOpmètre®;
- patients who provided written informed consent to participate in the study.

2.4. Non-Inclusion Criteria

The following patients were not included:

- patients with major cardiac arrhythmias likely to affect pulse wave velocity measurement;
- patients with unstable acute conditions;
- patients with incomplete clinical data;
- patients who refused to participate in the study.

2.5. Sampling

A consecutive and exhaustive recruitment of all eligible patients meeting the inclusion criteria was performed during the study period in order to minimize selection bias.

2.6. Data Collection

Data were collected from medical records, clinical interviews, and measurements performed during outpatient consultations.

The variables collected included sociodemographic data such as age, sex, socioeconomic level, and occupational status. Clinical data and cardiovascular risk factors were also recorded, including hypertension, diabetes mellitus, dyslipidemia, smoking status, body mass index (BMI), and history of cardiovascular disease.

Blood pressure was measured using a validated automated sphygmomanometer

after at least 5 minutes of rest in the seated position, in accordance with international recommendations. Hypertension was defined as a systolic blood pressure \geq 140 mmHg and/or a diastolic blood pressure \geq 90 mmHg, or current use of anti-hypertensive medication.

2.7. Assessment of Arterial Stiffness

Arterial stiffness was assessed using finger-to-toe pulse wave velocity (ftPWV) measured with the pOpmètre® (Axelife), a non-invasive device based on photoplethysmography.

Measurements were performed in a quiet room, with the patient in the supine position after at least 10 minutes of rest. Two photoplethysmographic sensors were placed on the index finger and the ipsilateral toe. The device automatically measured pulse transit time and calculated ftPWV. Elevated PWV was defined according to the manufacturer's reference values and published literature.

2.8. Ambulatory Blood Pressure Monitoring

Ambulatory blood pressure monitoring (ABPM) was performed using a **CONTEC® device, model ABPM50**, which allows automated blood pressure recording over a 24-hour period.

2.9. Measurement of Arterial Stiffness

Arterial stiffness was assessed using **digital toe pulse wave velocity (ftPWV)** measured with the **pOpmètre® (Axelife® SAS, France)**, a non-invasive device based on photoplethysmography that records the pulse wave transit time between the finger and the toe.

2.10. Measurement Procedure

Measurements were performed in **outpatients during consultation in a quiet room after a period of rest.**

Two photoplethysmographic sensors were placed simultaneously:

- one on the **finger**,
- the other on the **toe**.

The device automatically calculated:

- the **pulse wave transit time** between the two sites,
- and subsequently the **digital toe pulse wave velocity (ftPWV)**.

2.10.1. Quality Control and Validity of Measurements

Measurements were considered **invalid** in the following situations:

- device reading failure,
- poor-quality photoplethysmographic signal,
- presence of technical artifacts,
- interruption or improper acquisition of the recording.

In such cases, the measurement was **repeated**, or the patient was **excluded from**

the analysis if no valid measurement could be obtained.

2.10.2. Handling of Repeated Measurements

The ftPWV value retained for analysis corresponded to the valid measurement recorded by the device, automatically calculated by the pOpmetre®.

2.10.3. Definition of Increased Arterial Stiffness

According to international ESC/ESH recommendations and consensus documents on arterial stiffness, a PWV ≥ 10 m/s was considered abnormal and indicative of increased arterial stiffness associated with higher cardiovascular risk.

2.11. Cardiovascular Risk Assessment

Global cardiovascular risk was estimated using the Framingham risk score, which incorporates age, sex, blood pressure, smoking status, and metabolic risk factors.

2.12. Statistical Analysis

Data were entered and analyzed using [SPSS version XX / R / Stata] software.

Quantitative variables were expressed as mean \pm standard deviation or median with interquartile range, depending on their distribution. Qualitative variables were presented as frequencies and percentages.

Comparisons between hypertensive and normotensive groups were performed:

- using the Student's t-test (or Mann-Whitney U test) for quantitative variables;
- using the Chi-square test (or Fisher's exact test) for qualitative variables.

Multivariate linear and/or logistic regression analyses were conducted to identify factors independently associated with increased arterial stiffness.

The level of statistical significance was set at $p < 0.05$.

2.13. Ethical Considerations

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Institutional authorization was obtained from the Urgences Cardio Clinic in Dakar prior to the initiation of data collection. Patient data were handled confidentially and anonymized to ensure privacy and data protection.

This study was conducted with the authorization of the healthcare facility and in compliance with patient confidentiality and informed consent requirements.

3. Results

3.1. General Characteristics of the Study Population

During the study period, a total of 155 patients were seen at the Urgences Cardio Clinic in Dakar for ambulatory blood pressure monitoring (ABPM). Among them, 107 patients were included in the final analysis after the exclusion of 48 patients due to non-interpretable ABPM recordings ($n = 13$), invalid arterial stiffness measurements with the pOpmetre® ($n = 11$), and refusal to participate ($n = 24$) (Figure 1).

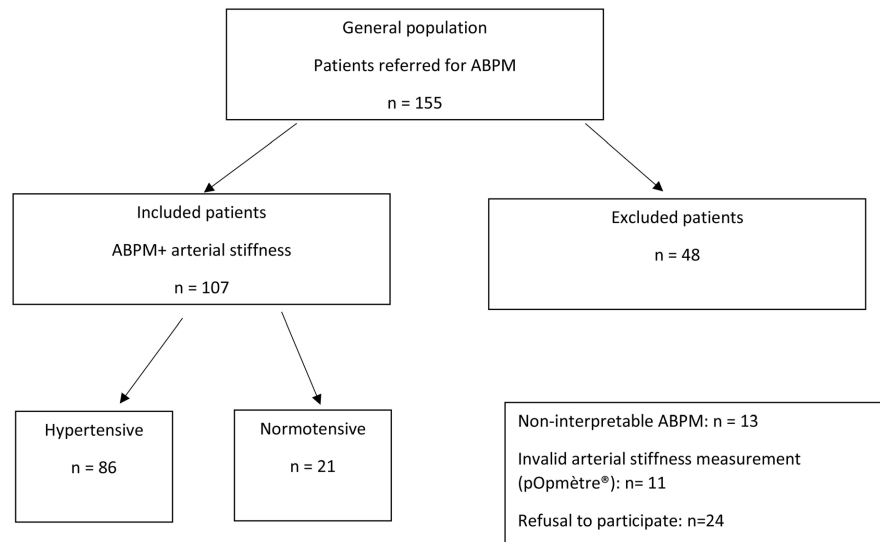


Figure 1. Flowchart of patient selection. ABPM: ambulatory blood pressure monitoring.

Among the 107 participants included, 86 (80.4%) were hypertensive and 21 (19.6%) were normotensive.

The mean age of the study population was 54.16 years, ranging from 22 to 83 years. The mean age was 56.96 years in men and 51.79 years in women ($p = 0.054$). Hypertensive patients were significantly older than normotensive subjects (56.36 years versus 45.14 years; $p = 0.008$). The population was predominantly composed of individuals aged 50 years and older (62.6%).

3.2. Anthropometric Data and Cardiovascular Risk Factors

The mean body mass index (BMI) was 29.83 kg/m², with a prevalence of obesity of 42.5% and overweight of 41.5%. The main cardiovascular risk factors were hypertension (80.4%), abdominal obesity (75.7%), family history of hypertension (62.62%), physical inactivity (50.47%), diabetes mellitus (20.56%), smoking (8.41%), and alcohol consumption (23.36%) (**Table 1**).

Table 1. Clinical characteristics of the study population according to sex.

Variables	Total 107 (100%)	Men 49 (45.8%)	Women 58 (54.2%)	p-value
Smoking	9 (8.41%)	5 (10.20%)	4 (6.90%)	0.124
Alcohol consumption	25 (23.36%)	13 (26.53%)	12 (20.69%)	0.477
Family history of hypertension	67 (62.62%)	27 (55.10%)	40 (68.97%)	0.140
Hypertension	86 (80.4%)	40 (81.63%)	46 (79.31%)	0.755
Diabetes mellitus	22 (20.56%)	10 (20.41%)	12 (20.69%)	0.971
Physical inactivity	54 (50.47%)	23 (46.94%)	31 (53.45%)	0.502
Abdominal obesity	81 (75.7%)	29 (59.18%)	52 (89.66%)	0.0001
Overweight	44 (41.12%)	18 (36.73%)	26 (44.83%)	0.088
Obesity	45 (42.06%)	19 (38.78%)	26 (44.83%)	—

Abdominal obesity was significantly more frequent in women than in men (89.66% versus 59.18%; $p = 0.0001$).

According to the Framingham risk score, 28.0% of patients had a high global cardiovascular risk, with a predominance in men (**Table 2**).

Table 2. Global cardiovascular risk assessment according to the Framingham score and sex.

Framingham risk score	Total (n = 25)	Men (n = 12)	Women (n = 13)	p-value
Low (<10%)	8	3 (37.5%)	5 (62.5%)	0.672
Intermediate (10% - 19%)	10	4 (40.0%)	6 (60.0%)	0.6882
High (>20%)	7	5 (71.4%)	2 (28.6%)	0.201

3.3. Arterial Stiffness and Pulse Wave Velocity

A substantial proportion of participants exhibited abnormal arterial stiffness, defined as finger-to-toe pulse wave velocity (ftPWV) ≥ 10 m/s.

ftPWV increased progressively with age, reflecting the impact of vascular aging on the loss of arterial distensibility. Linear regression analysis demonstrated a positive and statistically significant correlation between age and PWV ($p = 0.010$) (**Figure 2**).

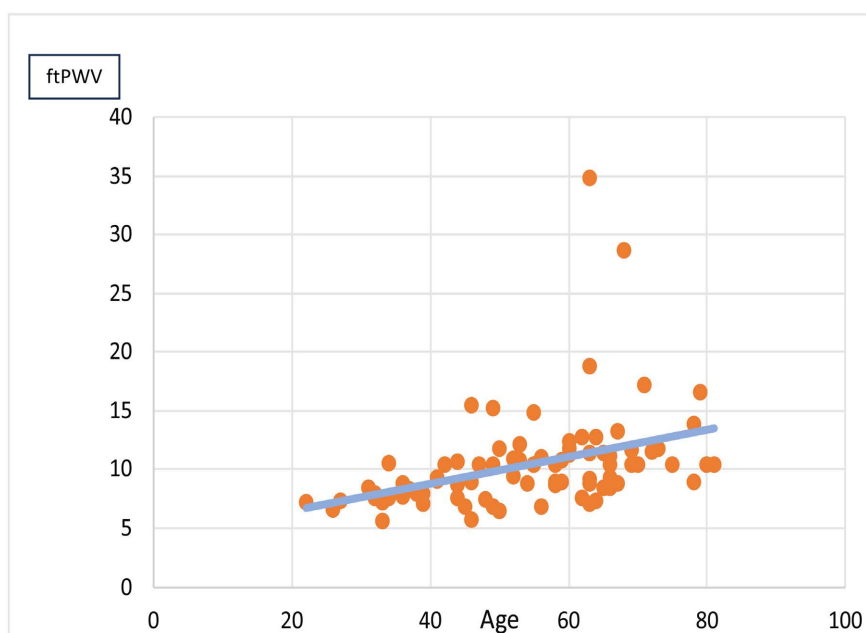


Figure 2. Linear regression model illustrating the correlation between age and pulse wave velocity.

3.4. Arterial Stiffness and Ambulatory Blood Pressure Parameters

The mean finger-to-toe pulse wave velocity (ftPWV) was significantly higher in patients with nocturnal systolic hypertension compared with those without nocturnal systolic hypertension (11.52 ± 4.97 m/s versus 9.32 ± 1.91 m/s; $p = 0.016$).

Furthermore, normal ftPWV values were more frequently observed in cases of nocturnal diastolic hypertension (81.3% versus 51.1%; $p = 0.025$).

Analysis of ambulatory blood pressure profiles also showed that a diastolic reverse dipper pattern was more common among subjects with normal ftPWV than among those with abnormal ftPWV (75.0% versus 25.0%; $p = 0.035$) (Table 3).

Table 3. Paraclinical characteristics of the study population according to mean finger-to-toe pulse wave velocity (ftPWV).

Variables	Category	Mean ftPWV (m/s)	p-value
24-hour systolic hypertension	Yes	10.80 ± 5.08	0.623
	No	10.75 ± 5.26	
24-hour diastolic hypertension	Yes	10.45 ± 5.19	0.462
	No	10.80 ± 5.10	
Daytime systolic hypertension	Yes	10.97 ± 5.25	0.701
	No	10.83 ± 5.19	
Daytime diastolic hypertension	Yes	11.50 ± 4.63	0.873
	No	11.55 ± 4.60	
Nocturnal systolic hypertension	Yes	11.52 ± 4.97	0.016
	No	9.32 ± 1.91	
Nocturnal diastolic hypertension	Yes	11.34 ± 3.52	0.656
	No	11.90 ± 6.27	
Elevated pulse pressure	Yes	12.65 ± 7.09	0.058
	No	9.96 ± 3.76	
Systolic dipping pattern	Reverse dipper	10.66 ± 3.03	0.86
	Non-dipper	10.55 ± 4.82	
	Dipper	10.71 ± 6.40	
	Extreme dipper	—	
Diastolic dipping pattern	Reverse dipper	9.52 ± 2.29	0.349
	Non-dipper	9.89 ± 2.82	
	Dipper	11.57 ± 6.37	
	Extreme dipper	7.23 ± 2.62	

3.5. Cardiovascular Risk Factors and Arterial Stiffness

Analysis of the cumulative burden of cardiovascular risk factors showed that normotensive subjects more frequently had a single risk factor compared with hypertensive patients (23.81% versus 4.65%; $p = 0.013$).

Overall, arterial stiffness was common in this outpatient population followed in Dakar and occurred in a context of a high burden of cardiovascular risk factors, with age and nocturnal blood pressure load playing a central role in the increase of finger-to-toe pulse wave velocity (ftPWV) (Table 4).

Table 4. Characteristics of the population with and without elevated pulse wave velocity according to the number of cardiovascular risk factors and blood pressure status.

Hypertension	Number of CV risk factors	Normal PWV (<10 m/s)	Abnormal PWV (≥10 m/s)	Total	p-value
Yes	1	3 (6.5%)	1 (2.5%)	4 (4.7%)	0.322
	2	8 (17.4%)	3 (7.5%)	11 (12.8%)	
	3	8 (17.4%)	4 (10.0%)	12 (14.0%)	
	4	13 (28.3%)	10 (25.0%)	23 (26.7%)	
	5	9 (19.6%)	14 (35.0%)	23 (26.7%)	
	6	4 (8.7%)	5 (12.5%)	9 (10.5%)	
	7	0 (0.0%)	2 (5.0%)	2 (2.3%)	
	8	1 (2.2%)	1 (2.5%)	2 (2.3%)	
No	1	5 (35.7%)	0 (0.0%)	5 (23.8%)	0.382
	2	3 (21.4%)	1 (14.3%)	4 (19.0%)	
	3	2 (14.3%)	3 (42.9%)	5 (23.8%)	
	4	2 (14.3%)	2 (28.6%)	4 (19.0%)	
	5	2 (14.3%)	1 (14.3%)	3 (14.3%)	
	6	0 (0.0%)	0 (0.0%)	0 (0.0%)	
	7	0 (0.0%)	0 (0.0%)	0 (0.0%)	
	8	0 (0.0%)	0 (0.0%)	0 (0.0%)	

4. Discussion

The present study, conducted among 107 outpatients followed in Dakar, highlights a high prevalence of arterial stiffness in a population characterized by a substantial burden of cardiovascular risk factors, notably hypertension (80.4%), abdominal obesity (75.7%), and a mean body mass index of 29.83 kg/m², with 42.5% obesity and 41.5% overweight. These findings reflect the epidemiological transition observed in sub-Saharan Africa, marked by a rising burden of cardiovascular diseases related to urbanization and lifestyle changes [1] [8].

4.1. Vascular Aging and Arterial Stiffness

One of the main findings of our study is the positive and statistically significant correlation between age and finger-to-toe pulse wave velocity (ftPWV) ($p = 0.010$), indicating a progressive increase in arterial stiffness with advancing age. This result is fully consistent with the international literature showing that pulse wave velocity increases steadily with age due to elastic fiber fragmentation, increased collagen deposition, and progressive vascular remodeling [3] [9].

Thus, in our population, predominantly composed of middle-aged adults, the observed increase in arterial stiffness already reflects notable vascular aging, confirming that age is the most consistent determinant of arterial stiffness, as reported in large international cohorts [10] [11].

4.2. Hypertension and Nocturnal Blood Pressure Load

Our study demonstrates that nocturnal blood pressure load plays a major role in the increase of arterial stiffness. Indeed, mean ftPWV was significantly higher in patients with nocturnal systolic hypertension compared with those without nocturnal hypertension (11.52 ± 4.97 m/s versus 9.32 ± 1.91 m/s; $p = 0.016$).

These findings are in line with pathophysiological data showing that prolonged exposure to elevated blood pressure, particularly during the period, promotes stiffening of large arteries through increased wall stress and impaired vascular compliance [4]. Moreover, the higher ftPWV observed in hypertensive patients, especially in the presence of nocturnal hypertension, underscores the specific role of nocturnal hemodynamic load in vascular aging [12].

Furthermore, the association between normal ftPWV and nocturnal diastolic hypertension (81.3% versus 51.1%; $p = 0.025$), as well as the higher frequency of a diastolic reverse-dipper profile among subjects with normal ftPWV (75.0% versus 25.0%; $p = 0.035$). These findings should be interpreted with caution. Indeed, they were not associated with a significant increase in mean digital toe pulse wave velocity (ftPWV) across the different diastolic dipping categories. This suggests that the observed results may reflect the effect of a small sample size, instability within the subgroups, or sensitivity to the categorization thresholds rather than a true pathophysiological relationship.

These observations are consistent with previous studies showing that abnormalities in nocturnal dipping patterns constitute a marker of increased cardiovascular risk and subclinical vascular damage [13].

4.3. Interaction of Cardiovascular Risk Factors in the Progression of Arterial Stiffness

Our population exhibited a high accumulation of cardiovascular risk factors, with abdominal obesity being significantly more frequent in women than in men (89.66% versus 59.18%; $p = 0.0001$). In addition, normotensive subjects more frequently had a single cardiovascular risk factor compared with hypertensive patients (23.81% versus 4.65%; $p = 0.013$), confirming the role of cumulative risk factor burden in the progression of vascular aging.

The literature indicates that obesity, diabetes, physical inactivity, and hypertension synergistically contribute to increased arterial stiffness through inflammatory, metabolic, and hemodynamic mechanisms [14]. In our study, the high prevalence of these factors, together with 28% of patients classified as high cardiovascular risk according to the Framingham score, supports the concept of arterial stiffness as an integrative marker of global cardiovascular risk.

4.4. Clinical Relevance of the pOpmètre® in the African Context

From a practical perspective, the assessment of arterial stiffness using ftPWV with the pOpmètre® proved to be feasible, rapid, and non-invasive in our clinical setting in Dakar, making it a relevant tool for the early detection of vascular aging in

resource-limited environments. Validation studies have demonstrated a good correlation between digital-to-toe PWV and conventional measures of arterial stiffness, supporting its usefulness in both clinical practice and research [7].

In an African context characterized by limited access to sophisticated vascular assessment techniques, the integration of ftPWV measurement alongside 24-hour ambulatory blood pressure monitoring (ABPM) could improve cardiovascular risk stratification and the early identification of high-risk patients.

4.5. Study Limitations

This study has some limitations, including its single-center design, relatively small sample size, and the specific socio-economic profile of the study population, which may limit the generalizability of the findings. In addition, the cross-sectional nature of the study does not allow causal relationships between arterial stiffness and blood pressure parameters to be established. Nevertheless, the consistency of our findings with international data strengthens their external validity.

5. Conclusion

Our results show that arterial stiffness, assessed by ftPWV, is closely associated with age, hypertension, and particularly nocturnal blood pressure load, confirming its central role as a marker of vascular aging and global cardiovascular risk in an African outpatient population. These findings support the value of a combined approach using 24-hour ABPM and arterial stiffness assessment to optimize the management of hypertensive patients in sub-Saharan Africa.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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