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# Comparative Study of Ambulatory Blood Pressure Monitoring and Clinic Blood Pressure Measurement in the Risk Assessment and Management of Hypertension

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# دراسة مقارنة بين تسجيل قراءات ضغط الدم على مدى أربع وعشرين ساعة والقراءة السريرية في تقويم خطورة وعلاج ارتفاع ضغط الدم

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**الخلاصة: الهدف:** قياس ضغط الدم في العيادة لا يمثل قراءته خلال اليوم، ولهذا فان قياس ضغط الدم الجوال يتغلب على هذه المشكلة بتزويده قراءات متعددة من دون أن يؤثر بشكل كبير على فعاليات المريض اليومية. الهدف من هذه الدراسة تقييم مدى فاعلية المراقبة الجوالة لضغط الدم لمدة أربع وعشرين ساعة ومقارنتها بالقياسات السريرية التقليدية من حيث خطورة وعلاج ارتفاع ضغط الدم. **الطريقة:** شملت الدراسة 104 مريضا مصابا بارتفاع ضغط الدم الأولي سواء تلقوا علاجا سابقا لارتفاع ضغط الدم أم لا للفترة من يناير 2007 الى ديسمبر 2009. وقد خضع كل المرضى للإجراءات الآتية: 1. قياسات دورية لضغط الدم بالعيادة الخارجية 2. عينات دم للفحوصات الروتينية 3. فحص تَخْطيط كَهْرَبِيَّة القَلْب وتَخْطيط صَدَى القَلْب 4. المراقبة الجوالة لقياس ضغط الدم لمدة أربع وعشرين ساعة. **النتائج:** كان متوسط عمر المرضى 8.6 ± 41.1 سنة، وكان (51.9%) منهم من الرجال . كانت دواعي استعمال قياس ضغط الدم الجوال: الشك بوجود ارتفاع ضغط الدم بسبب الغلالَة البَيضاء(10.6%)، ضغط الدم المفاجيء (18.2%)، ضغط الدم المقاوم (27.9%)، وأنواع أخرى من ضغط الدم (3.34%). كان متوسط ضغط الدم في النهار (134/82 ملم زئبقي) وفي الليل (124/73 ملم زئبقي). لوحظ طراز غير متذبذب في (4.46%). أظهر تَخْطيطُ صَدَى القَلْب تضخم البطين الأيسر(22.1%) كما أظهر الاضطراب الانبساطي في (29.8%). من الناحية الإحصائية كان قياس ضغط الدم الجوال أكثر ارتباطا مع اضطراب البطين الانبساطي من النوع الآخر ($P$= 0.043). الأشخاص الذين كان لديهم ارتفاع في ضغط الدم بسبب الغلالَة البَيضاء لم يعطوا علاجا. **الخلاصة:** لاتزال المراقبة الجوالة لضغط الدم لمدة أربع وعشرين ساعة أداة قليلة الاستخدام في تقويم خطورة وعلاج مرضى ارتفاع ضغط الدم رغم أهميتها. و قد كشفت الدراسة عن تفوق هذه الطريقة على القياسات السريرية التقليدية بالعيادة الخارجية.

**مفتاح الكلمات:** ارتفاع ضغط الدم، مراقبة ضغط الدم، جوال، تضخم، بطين أيسر، خلل أداء البطين، أيسر.

**ABSTRACT:** ***Objectives:*** Blood pressure (BP) measurements taken in a physician's clinic do not represent readings throughout the day. Ambulatory blood pressure monitoring (ABPM) overcomes this problem by providing multiple readings with minimal interference with the patient's daily activities. The purpose of our study was to evaluate the value of ABPM in risk assessment and management of hypertension compared to office measurements. ***Methods:*** A total of 104 consecutive hypertensive patients were retrospectively studied from January 2007 to December 2009. The following data were gathered: 1) clinic BP measurements; 2) routine blood test results; 3) electrocardiography, echocardiography, and 4) 24-hour ABPM. ***Results:*** The mean age of patients was 41.1 ± 8.6 years and 51.9% of them male. Indications for ABPM were: suspected "white coat" hypertension (10.6%), *de novo* hypertension (18.2%), resistant hypertension (27.9%) and others (43.3%). Mean daytime and nighttime BP were 134/82 and 124/73 mmHg respectively. A non-dipping pattern was reported in 64.4%. Echocardiographic evidence of left ventricular hypertrophy (LVH) and diastolic dysfunction (LVDD) was encountered in 22.1% and 29.8% respectively. ABPM parameters were significantly correlated with LVDD ($P$ = 0.043). Patients with proved "white coat" hypertension did not receive antihypertensive therapy. ***Conclusion:*** Twenty-four hour ABPM is an important yet underused tool for proper risk stratification of treated hypertensive patients. The non-dipping profile is associated with a higher incidence of diastolic dysfunction. Our collective results revealed the superiority of ABPM over office BP measurement.

***Keywords:*** Hypertension; Blood pressure monitoring, ambulatory; Hypertrophy; Left Ventricular; Ventricular Dysfunction, Left.

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**Advances in Knowledge**

1. *The present study sheds light on the important role of 24-hour ambulatory blood pressure monitoring (ABPM) in the management and risk stratification of hypertensive patients.*
2. *It draws attention to the advantages of this procedure and compares our results with studies in the available literature.*

**Application to the patient care**

1. *In patients with treated hypertension, a higher ambulatory systolic or diastolic BP predicts adverse cardiovascular events.*
2. *ABPM provides useful information for determining which patients have isolated office hypertension and in guiding drug regimen modification.*

Over the past three decades, the accuracy of using the conventional sphygmomanometer to measure blood pressure (BP) has been questioned, and efforts have been made to improve measurements with automated devices.[1] Ambulatory blood pressure monitoring (ABPM) is being increasingly recommended for routine clinical practice. It may be particularly useful in evaluating the patient with variable BP readings in the office, or the patient with wide discrepancies between BP readings at home and in the physician's office (i.e. "white coat" hypertension). ABPM and, in particular, nocturnal BP readings, may also provide prognostic data.[2,3] This has focused attention on methods of measurement that provide profiles of BP rather than rely on isolated measurements made under circumstances that may influence BP.[4] Early clinical uses of ABPM were limited in identifying patients with white-coat hypertension; however, ABPM has evolved into a useful modality for stratifying cardiovascular risk and guiding therapeutic decisions. Left ventricular hypertrophy (LVH) is an important predictor of cardiovascular morbidity and mortality.[5] The prevalent circadian pattern in both normotensive and hypertensive individuals is characterised by a marked decrease of systolic and diastolic BP during the night (dippers), but there is a noticeable fraction of subjects who exhibit a diminished nocturnal decline in BP (non-dippers).[6] Many clinical studies with non-invasive ABPM have shown that some cardiovascular complications of hypertension, namely LVH, tend to be more frequent in patients in whom BP does not fall, or falls only minimally at night and who consequently, suffer a prolonged exposure to high BP levels over 24 hours.[7,8] The purpose of our study was to evaluate the value of 24-hour ABPM in the risk assessment and management of hypertension compared to the traditional office measurements.

## Methods

This retrospective study included 104 existing or newly diagnosed essential hypertensive patients attending the out-patient Cardiology Clinic at Sultan Qaboos University Hospital, Oman, from January 2007 to December 2009. Only records of patients with at least three readings showing diastolic BP ≥ 90 mmHg and/or systolic BP ≥ 140 mmHg, or established hypertensive patients who were currently on treatment were included. All patients had to have undergone the following procedures: 1) detailed history taking, general and cardiovascular examination including repeated clinic BP measurements; 2) blood sampling for routine chemistry examinations; 3) 12-leads electrocardiography, transthoracic echocardiography, and 4) 24-hour ABPM. Patients with congestive heart failure, previous myocardial infarction, significant cardiac valve diseases, or poor echocardiography window were excluded.

BP was measured from both of the patient's arms in the hospital's out-patient clinic by a dedicated nurse using a well calibrated automated BP machine (Datascope: Trio, China, 2005), and after the patient had rested for 5 minutes in the sitting position. The higher reading was recorded.

Twenty-four-hour ABPM was carried out on the arm with the higher reading using a (24/48 hour BP recorder, (BR-102 plus, Schiller, Switzerland, 2006). The device was set to obtain BP readings at 30 minutes interval during the daytime and at 60 minutes interval during night-time according to the patient's lifestyle. Daytime and nighttime were individually predetermined depending upon the individual patient's awake and sleep times; for example, if a patient normally woke at 6 am and went to sleep at 10 pm, his or her daytime recordings were taken from 6 am to 10 pm and nighttime ones from 10 pm to 6 am. The patients were instructed to continue with their usual daily activities, but to

**Table 1:** Baseline clinical characteristics of the study population

| Parameter | Result |
|---|---|
| Age in years ± standard deviation | 41.1 ± 8.6 |
| Male gender % | 51.9 |
| Dyslipidemia % | 21.2 |
| Diabetes mellitus % | 13.4 |
| Renal impairment % | 6.7 |
| Obstructive sleep apnea %? | 1.9 |
| Cerebrovascular accident % | 3.8 |
| Hypertension Duration/years | 4.7 ± 6.03 |
| Office systolic blood pressure mmHg | 146.9 ± 22.7 |
| Office diastolic blood pressure mmHg | 86.6 ± 13.7 |
| Mean office heart rate beats per minute | 63.0 ± 24.1 |

remain still at measurement times. The recording was then analysed to obtain 24-hour daytime and night-time average systolic blood pressure (SBP), diastolic blood pressure (DBP) and heart rates. Only SBP was used to assess dipping.

Two-dimensional, M-mode, and Doppler echocardiographic examinations were performed using the commercially available instruments (Acuson Sequoia 265, USA, 2003 and Geving MED system V, Norway, 2000). End-diastolic and end-systolic left ventricular internal diameter (LVIDd and LVIDs); interventricular septum thickness (IVST); posterior wall thickness (PWT); ejection fraction (EF) and fractional shortening (FS) were calculated from two-dimensionally guided M-mode tracing. Left ventricular filling to evaluate diastolic function was assessed by recording mitral flow and the ratio of the early to late flow velocity peaks (E/A ratio) was assessed.

A 'non-dipping BP profile' is defined as a nocturnal systolic BP fall of less than 10% compared to daytime values.[6,9] Left ventricular hypertrophy is defined as increased left ventricular mass as assessed by 2D guided M-mode echocardiographic examination of interventricular septum and posterior wall thickness in diastole equal to more than 1.2 cm.[10] Left ventricular diastolic dysfunction is defined as abnormality in the left ventricle's filling during diastole as assessed by the utility of mitral annulus Doppler flow velocity with reversed E/A ratio.[11] There is no consensus definition of borderline hypertension; however, some studies in the literature have defined borderline HTN as

**Table 2:** Indications of ambulatory blood pressure monitoring

| Indication | % |
|---|---|
| Suspected "white coat" HTN | 10.6 |
| Recent onset HTN | 18.2 |
| Resistant HTN | 27.9 |
| Borderline HTN | 16.3 |
| Orthostatic hypotension | 7.7 |
| Episodic HTN with symptoms | 19.3 |

*Legend: HTN = hypertension*

"prehypertension" described as systolic BP 135-139 mmHg *and/or* diastolic BP 85-89 mmHg.[12] The term "white coat" hypertension is applied to patients with office readings that average more than 140/90 mmHg and reliable out of office readings that average less than 140/90 mmHg.[4] Resistant hypertension is defined in the 2008 American Heart Association scientific statement as BP that remains above goal in spite of concurrent use of three antihypertensive agents of different classes. Thus, patients whose BP is controlled with four or more medications should be considered to have resistant hypertension.[13] Orthostatic hypotension is defined as at least a 20 mmHg fall in systolic pressure and or 10 mmHg fall in diastolic pressure after quiet standing for 2 minutes.[14] Episodic (paroxysmal) HTN with symptoms is defined as an abrupt elevation of BP that is documented by a clinician or home BP monitor associated with abrupt onset of distressful physical symptoms, such as headache or palpitation.[15]

Statistical analyses were carried out using the Statistical Package for the Social Sciences (SPSS), Version 15, (SPSS Inc., Chicago, IL). Continuous data were expressed as mean value ± standard deviation (SD) and categorical data as percentages. Continuous variables were compared using the Student's paired t-test. Categorical data were compared using chi-square ($X^2$) analysis. Data were first identified in a univariate fashion with linear regression analysis for continuous variables and $X^2$ test for dichotomous variables. A *P* value of 0.05 or less was considered statistically significant.

## Results

The demographic and clinical characteristics of the study population are reported in Table 1. The

**Table 3:** Ambulatory blood pressure monitoring (ABPM) parameters

| Parameter | mmHg |
|---|---|
| Mean 24 hour SBP | 131.2±14.8 |
| Mean 24 hour DBP | 79.5 ±9.3 |
| Mean daytime SBP | 133.9 ± 15.3 |
| Mean daytime DBP | 81.7 ± 9.7 |
| Mean nighttime SBP | 123.6 ± 14.7 |
| Mean night-time DBP | 73.4 ± 9.4 |
| Mean dipping % | 8.2 ± 4.8 |
| Dipper % | 35.6 |

*Note: Many ABPM parameters have been proposed. This table illustrates some of those commonly used. From this table, it is clear that, only 35.6% of patients could be considered as dippers. Legend: SBP = systolic blood pressure; DBP = diastolic blood pressure*

**Table 4:** Baseline electrocardiogram and echocardiography findings

| Parameter | Result |
|---|---|
| ECG-LVH % | 6.7 |
| Echo-LVH % | 22.1 |
| LVEDD/mm | 48.3 ± 5.3 |
| LVESD/mm | 29.6 ± 4.8 |
| IVST/mm | 10.9 ± 1.7 |
| PWT/mm | 10.3 ± 1.6 |
| EF % | 68.1 ± 6.7 |
| FS % | 38.3 ± 5.8 |
| LV diastolic dysfunction % | 29.8 |

*Legend: ECG = electrocardiography; LVH = left ventricular hypertrophy; Echo = echocardiography; LVEDD/mm = left ventricular end diastolic diameter; LVESD = left ventricular end systolic diameter; IVST = interventricular septal thickness; PWT = posterior wall thickness; EF = ejection fraction; FS = fractional shortening; LV= left ventricular.*

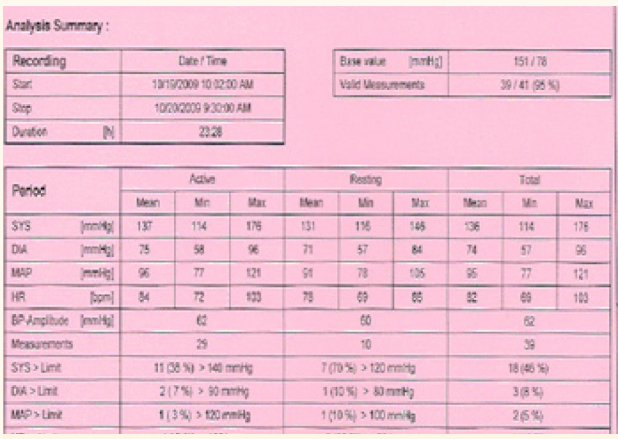
mean age of the patients was 41.1 ± 8.6 years, with slightly more males than females (51.9%). Mean office SBP and DBP were 146.9 ± 22.7 and 86.6 ± 13.7 mmHg respectively. Hypertension duration was reported as 4.7 ± 6.03 years; however, we declare that in our database we could not find the exact duration of hypertension for all patients. Table 2 illustrates our indications of ABPM. Table 3 illustrates ABPM parameters. From this latter table, it is clear that, only 35.6% of patients showed a fall in SBP/DBP > 10% during nighttime compared to daytime measurements and were categorised as dippers, while the remaining 64.4% showed a fall ≤ 10% and were categorised as non-dippers. There were significant differences between systolic and diastolic BP measured at the office and the mean 24-hour systolic and diastolic BP measured by ABPM with $P$ = 0.0001. Table 4 depicts the electrocardiogram (ECG) and echocardiographic findings. LVH was reported in 6.7% of analysed ECG readings; however, it was remarkably higher, 22.1% of the study population, when measured by echocardiography. Left ventricular diastolic dysfunction was noted in 29.8% of our patients.

As to circadian BP variation and cardiac structure and function, when the echocardiographic data were analysed in a categorical way as a presence or absence of LVH, the prevalence of LVH was similar in dippers and non-dippers ($P$ = 0.09). A significant correlation was found between left ventricular diastolic dysfunction and mean systolic and diastolic daytime BP ($P$ < 0.043).

## Discussion

The purpose of our present study was to observe whether or not 24-hour ABPM improved the risk assessment and management of hypertensive patients. By its unique 24-hour BP evaluation outside the medical field, ABPM was considered to be an effective tool to assess the average BP over the day in addition to circadian variation. Many prospective studies have reported that such measurements give a better prediction of clinical outcomes compared to conventional clinic measurements. Currently, it is the only tool available to exclude the well known phenomenon of "white coat" hypertension and has a role in assessing apparent drug-resistant hypertension, hypertension in pregnancy, during symptomatic episodes of hypotension or hypertension, and in monitoring adequacy of BP control in patients at high risk of cardiovascular disease.[2-4]

According to circadian variation in BP, ABPM allows stratification into "dipper" or "non-dipper" status. In our study, we found 64.4% of patients were non-dippers. As many studies have related target organ damage to the non-dipping phenomenon,[6] we intended to optimise the BP of those patients, especially diabetics. The interesting finding was that 16.6% of the non-dippers were found to have a normal ambulatory blood pressure (ABP) profile. There is as yet no consensus about the proper management strategy for non-dippers with a



Analysis Summary :

| Recording | Date / Time |
|---|---|
| Start | 10/19/2009 10:02:00 AM |
| Stop | 10/20/2009 9:30:00 AM |
| Duration [h] | 23:28 |

| Base value [mmHg] | 151 / 78 |
|---|---|
| Valid Measurements | 39 / 41 (95 %) |

| Period | | Active | | | Resting | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max |
| SYS | [mmHg] | 137 | 114 | 176 | 131 | 116 | 146 | 136 | 114 | 176 |
| DIA | [mmHg] | 75 | 58 | 96 | 71 | 57 | 84 | 74 | 57 | 96 |
| MAP | [mmHg] | 96 | 77 | 121 | 91 | 78 | 105 | 95 | 77 | 121 |
| HR | [bpm] | 84 | 72 | 103 | 78 | 69 | 88 | 82 | 69 | 103 |
| BP-Amplitude | [mmHg] | 62 | | | 60 | | | 62 | | |
| Measurements | | 29 | | | 10 | | | 39 | | |
| SYS > Limit | | 11 (38 %) > 140 mmHg | | | 7 (70 %) > 120 mmHg | | | 18 (46 %) | | |
| DIA > Limit | | 2 ( 7 %) > 90 mmHg | | | 1 (10 %) > 80 mmHg | | | 3 ( 8 %) | | |
| MAP > Limit | | 1 ( 3 %) > 120 mmHg | | | 1 (10 %) > 100 mmHg | | | 2 ( 5 %) | | |

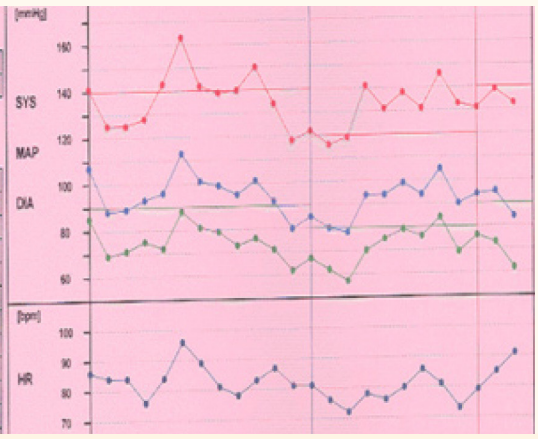



**Figure 1a** **Figure 1b**

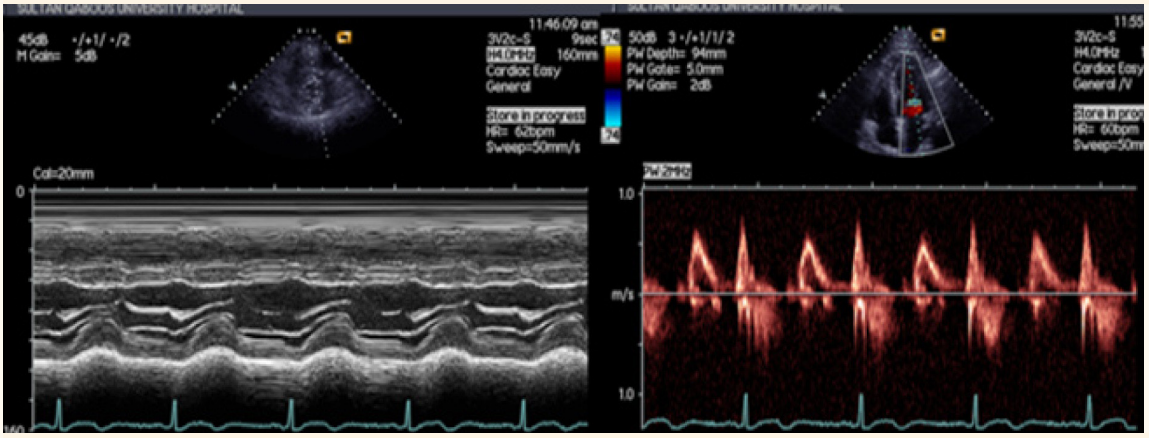



**Figure 1c** **Figure 1d**

**Figure 1:** Example graph from ambulatory blood pressure monitoring (ABPM) report of 62-year old male diabetic and hypertensive patient with normal average active, resting and total 24-hour blood pressure readings. It shows the association between non-dipper status [**1a & 1b**] and the echocardiographic evidence of left ventricular hypertrophy [**1c**] and diastolic dysfunction [**1d**]. Despite his office blood pressure measures being persistently high, the ABPM noticeably showed a "white coat" effect.

normal BP profile. We assume that the non-dipping group with a normal ABPM profile may be highly susceptible for future persistent hypertension requiring shorter-term follow-up by office and ABPM measurements [Figure 1a-d].

The association between diurnal BP profile and target organ damage remains controversial.[7,16] Our data are in agreement with several studies which failed to detect significant differences between dipper and non-dipper hypertensive patients and LVH assessed by either ECG or echocardiography.[17,18] Despite this, there was a trend towards increased incidence of LVH in the non-dipper group ($P$ = 0.09). The reduced nocturnal fall in BP was found in the majority of our study population (64.4%), and appeared particularly high in the group with resistant and refractory hypertension. Contradictory to the non-significant correlation between LVH and ABPM, left ventricular diastolic function was found to be closely related to ambulatory, rather than clinic BP measurements, the mean nocturnal diastolic BP being a powerful marker of LV filling impairment ($P$ = 0.043). This was in agreement with other studies which have addressed this issue.[19,20]

"White coat" hypertension was suspected in 10.6% of our study population (as they were not receiving any antihypertensive drug). One third of those patients had a normal ABP profile; many of them described attacks of dull aching internal discomfort just before attending the hospital and others described palpitation and flushing. Most of these patients had an elevated last BP reading before disconnecting the machine thus constituting the typical presentation of office hypertension. This is consistent with reports by many authors who found

that the incidence of this condition ranges from 15-48%.[21] This phenomenon can only be detected by ABPM and reported by some patients who have the facility of self-monitoring. Actually, most of those patients had either emotional or physical stress or a family history of hypertension. A high proportion of patients with borderline hypertension may actually exhibit "white coat" hypertension which exaggerates BP measurement immediately before arriving at the clinic. Measurements obtained by means of ABPM can provide additional information for risk stratification in patients with borderline elevations in BP.

Resistant hypertension is defined as the inability to reach a target BP lower than 140/90 mmHg despite 3 or more drug regimens in correct dosages. A total of 29% of our patients fulfilled this criterion. Interestingly, ABPM identified that 42% of them had controlled BP.

There are many limitations of the current study. The sample size was relatively small for a retrospective study; however, many studies with larger samples have shown similar results.[2] These data represent the acute outcome; however, our aim was to highlight the value of ABPM over traditional office BP measurements. Our study is still ongoing as we have subsequently added more patients and increased the range of indications and the follow-up duration.

## Conclusion

Ambulatory BP monitoring is an established and robust technology, but an underused tool in hypertension management and risk assessment either before or after drug treatments. Further prospective studies in selected group of patients are indicated.

### CONFLICT OF INTEREST

The auhtors reported no conflict if interest.

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