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Clinical Usefulness of Watch-PAT for Assessing the Surgical Results of Obstructive Sleep Apnea Syndrome

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SCIENTIFIC INVESTIGATIONS

Objective: This study aimed to assess the accuracy and clinical efficacy of a wrist-worn device that is based on peripheral arterial tonometry (watch-PAT) to evaluate the surgical results of obstructive sleep apnea (OSA) syndrome subjects.

Study Design and Method: Thirty-five subjects who were diagnosed with OSA and underwent sleep surgeries such as septoplasty, tonsillectomy, or uvuloplasty to correct their airway collapse, participated in this study; the watch-PAT-derived respiratory disturbance index (RDI), apnea and hypopnea index (AHI), lowest oxygen saturation, and valid sleep time were measured after the sleep surgery.

Results: The present study showed that RDI (32.8 ± 10.7 vs 14.8 ± 7.5), AHI (30.3 ± 8.6 vs 13.4 ± 8.2 events/h), lowest oxygen saturation (78.2% ± 8.4% vs 90.5% ± 7.1%), and valid sleep time (329.1 ± 47.2 min and a postoperative value of 389.1 ± 50.1 min) recovered to within a normal range after surgery in 28 subjects. In addition, good agreement was found between watch-PAT-derived factors and visual analogue scales for changes in subjective symptoms, such as snoring, apnea, and daytime somnolence. Seven of the 35 subjects showed no improvement for their subjective symptoms and complained of snoring and apnea after surgery. We found that the RDI and AHI of those 7 subjects were not reduced, and the changes between pre- and postoperative values which were measured with watch-PAT were minimal. Their postoperative lowest oxygen saturation and valid sleep time were not elevated per the watch-PAT. The results support a strong correlation between the findings from watch-PAT and improved symptoms after surgical correction of an airway collapse.

Conclusions: Our study provides evidence that the factors measured by the watch-PAT might be reliable indicators of symptomatic changes in OSA subjects after sleep surgery and also shows that the watch-PAT is a highly sensitive portable device for estimating treatment results in OSA.

Keywords: Obstructive sleep apnea, watch PAT, sleep surgery, airway collapse

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Sleep disordered breathing is a spectrum of diseases that includes snoring, upper airway resistance syndrome, and obstructive sleep apnea (OSA).[1] OSA is a common sleep disorder and is characterized by repeated episodes of partial or complete upper airway collapse during sleep, leading to poor sleep quality, sleep fragmentation, intermittent nighttime hypoxemia, reduced percentage of slow wave sleep, and increased sympathetic overdrive.[1,2] OSA may induce excessive daytime somnolence, morning headaches, poor concentration, and decreased quality of life.[1] If OSA persists without proper diagnosis and treatment, cardiovascular and neurocognitive disease may occur; consequently, early diagnosis of OSA is important for treatment and improvement of upper airway collapse.[2]

The gold standard for the diagnosis of OSA remains attended overnight full polysomnography (PSG). PSG monitors single or multiple physiologic variables during sleep.[3] PSG has been also used for assessing OSA severity and is useful in selecting treatment modalities for OSA. In addition, PSG allows clinicians to test the treatment results of OSA, such as continuous positive airway pressure (CPAP) and surgeries to improve airway collapse.[4] However, full PSG has several disadvantages, such as a relatively expensive cost, full nighttime occupation at the laboratory or hospital, sleep disturbances caused by the presence of too many probes or sensors, a long waiting list, and an unfamiliar sleep environment. As a result, there exists a need for more simple devices to diagnose OSA and to estimate the severity of OSA for proper treatment. Recently, many portable devices have been developed as an alternative to full PSG for the diagnosis of OSA.

The watch-PAT, which is a wrist-worn, portable device based on peripheral arterial tonometry (PAT), may be useful for the ambulatory detection of OSA.[5] The device is based on technology that uses a finger-mounted pneumo-optical sensor that eliminates venous pulsations and continuously measures the

BRIEF SUMMARY

Current Knowledge/Study Rationale: Although full polysomnography is the most exact and standard tool for diagnosis of obstructive sleep apnea (OSA). The watch-PAT, one of portable devices showed good concordance with PSG for diagnosing OSA and might be useful for efficient CPAP titration or treatment. However, there is controversy over whether the watch-PAT is able to evaluate the success rate of OSA improvement after surgical treatment.

Study Impact: We proposed that the sleep parameters measured through watch-PAT can provide useful information about diagnosis of OSA, and the watch-PAT may be efficiently applied to assess treatment results of sleep surgeries.

arterial pulse wave volume of the digit. Episodes of upper airway obstruction cause episodic vasoconstriction of digital vascular beds due to activation of the sympathetic nervous system, which results in attenuation of the PAT signal.[6] The diagnosis of OSA is possible with this device using only five parameters: PAT signal, heart rate, oxyhemoglobin saturation, wrist activity without the conventional measurements of airflow, and respiratory effort. Some studies have attempted to assess the accuracy of the watch-PAT to diagnose and evaluate severity of OSA[6,7]; although they had several limitations, the watch-PAT showed good concordance with PSG for diagnosing OSA. Also the watch-PAT had several advantages, such as inexpensive cost, wide accessibility, ease of use, lower risk, and few side effects. Some reports have shown that the watch-PAT might be useful in reassessing OSA patients for efficacy of CPAP treatment.[8] However, there is controversy over whether the watch-PAT is able to evaluate the success rate of OSA improvement after surgical treatment.

In the present study, we analyzed the clinical efficacy of both pre- and postoperative, overnight, in-house watch-PAT use as a full PSG substitution to assess OSA surgical results.

MATERIALS AND METHODS

Subjects

Thirty-five adult subjects who had been diagnosed with moderate or severe OSA in Chung-Ang University Hospital (Seoul, Korea) participated in the study; all subjects gave informed consent. These patients were required to fill out our hospital's sleep survey chart, which includes BMI, Epworth Sleepiness Scale (ESS), and visual analog scale (VAS) survey for snoring and apnea. Intranasal endoscope, cephalography, and drug-induced sleep endoscopy (DISE) were performed to evaluate airway narrowing and the exact site of airway collapse. All patients underwent DISE; among these patients, 25 showed severe narrowing (> 75%) of the nasopharynx and the retropalatal area. Of the remaining patients, 7 patients showed moderate narrowing (> 25%, < 75%) and 3 patients showed mild narrowing (< 25%) of the airway area. In cephalography, the mean posterior air space (PAS) was 8.1 ± 2.3 mm (reference range 11 ± 2 mm) and mandible plane to hyoid (MPH) was 12.5 ± 3.7 mm (reference range 19 ± 2 mm). Septal deviation, redundant uvula, or tonsil hypertrophy were observed in the subjects, and OSA was finally diagnosed using the watch-PAT 200 (Itamar Medical Ltd, Caesarea, Israel). CPAP was recommended as a primary OSA treatment, but the subjects had refused to wear the unit due to the long treatment duration and related sleep discomfort. For primary treatment, all 35 subjects received septoplasty, 23 subjects received uvuloplasty, and 12 subjects received tonsillectomy to correct airway narrowing. Exclusion criteria were as follows: (1) history of peripheral vasculopathy or autonomic nervous system dysfunction and mild OSA; (2) cardiac problems, severe lung disease, and use of α-adrenergic receptor-blocking agents; and (3) finger deformity that might affect application of the watch-PAT probe. In addition, we did not include the subjects who showed narrowed airway at tongue base and glottis. The subject population consisted of 27 males and 8 females. The mean body mass index was 22.3 kg/m^2, and mean age was 50.7 years.

Study Design and Statistical Analysis

All subjects completed a pre- and postoperative research survey that included a visual analogue scale (scale 1-10 where 10 was totally satisfied) for snoring and apnea, and an Epworth Sleepiness Scale was used to evaluate subjects' daytime sleepiness.[6] The watch-PAT was performed twice: once prior to the sleep surgery and 2 months after the surgery. The apnea-hypopnea index (pAHI), respiratory distress index (pRDI), lowest oxygen saturation, and valid sleep time were evaluated. To analyze the watch-PAT results, PAT studies were uploaded for automated analysis on a personal computer using the COMPACTFLASH reader provided with the PAT software (zzz_PAT version 1.5.44.7, Itamar Medical Ltd, Caesarea, Israel). Kendall tau-b was used to assess correlation and agreement between the surgical results and watch-PAT data. All analysis was performed with SPSS (version 18.0; SPSS Inc., Chicago, IL, USA) for Windows software. A p value < 0.05 was considered statistically significant.

RESULTS

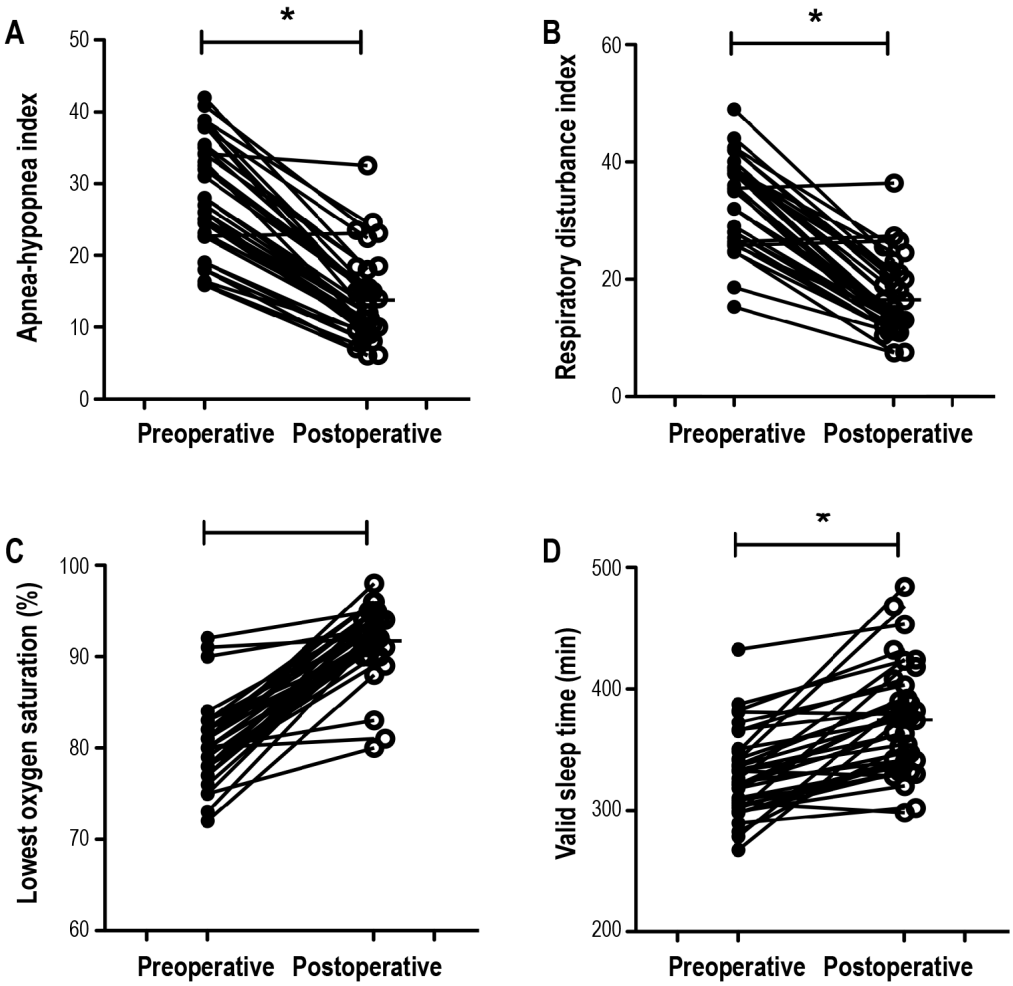
We recruited 35 subjects diagnosed with OSA and performed septoplasty, uvuloplasty, or tonsillectomy to resolve airway narrowing and to reduce airway collapse. Pre- and postoperative pAHI, pRDI, lowest oxygen saturation, and valid sleep time were evaluated. The mean pAHI for the 35 subjects was 30.3 ± 8.6 events/h when measured before sleep surgery using the watch-PAT, while the postoperative mean pAHI was 13.4 ± 8.2 events/h, showing a statistically significant reduction of pAHI after the sleep surgery (**Figure 1A**). The preoperative mean pRDI was 32.8 ± 10.7 events/h, while the postoperative mean pRDI was 14.8 ± 7.5 events/h; thus, postoperative pRDI was also significantly decreased after the sleep surgery (**Figure 1B**).

The pre-operative lowest oxygen saturation value was 78.2% ± 8.4% while the postoperative value was 90.5% ± 7.1%, a statistically significant improvement (**Figure 1C**). Also, there was a statistically significant improvement ($p < 0.05$) in valid sleep time, with a preoperative value of 329.1 ± 47.2 min and a postoperative value of 389.1 ± 50.1 min (**Figure 1D**).

These data show that surgical treatment for OSA is relatively successful when we analyze mean pAHI, pRDI, lowest oxygen saturation, and valid sleep time pre- and postoperatively using the watch-PAT. As a next step, we assessed the correlation between factors measured using the watch-PAT and the changes in subjective symptoms to determine whether the watch-PAT data were representative of an actual improvement in subjective symptoms after the sleep surgeries. Twenty-eight subjects showed good surgical results and were classified as the responder group. The VAS for snoring and apnea and the ESS scores for daytime somnolence were reduced after the sleep surgeries, and the pAHI, pRDI, lowest oxygen saturation, and valid sleep time from the watch-PAT were significantly improved. However, 7 of the 35 subjects who were classified as the non-responder group still complained of snoring, apnea, and daytime somnolence after the sleep surgery, and their pAHI, pRDI, lowest oxygen saturation, and valid sleep time from the watch-PAT had not significantly changed.

We then estimated the variability of pAHI, pRDI, lowest oxygen saturation, and valid sleep time and compared these

Figure 1—Change in watch-PAT-derived factors, such as AHI **(A)**, RDI **(B)**, low oxygen saturation **(C)**, and valid sleep time **(D)**, before and after sleep surgery (*p < 0.05 when compared with the levels between preoperative and postoperative)



changed values with the subjects' VAS and ESS scores to investigate the factors measured using the watch-PAT. **Figure 2** shows a scatter plot of change in pre- and postoperative snoring VAS score vs. change in pre- and postoperative pRDI. We found a high correlation (r = 0.785, $p < 0.05$) and good agreement between change in snoring VAS score and change in pRDI. Also, **Figure 2** shows a scatter plot of change in pre- and postoperative snoring VAS score vs. change in pre- and postoperative pAHI. We found a high correlation (r = 0.829, $p < 0.05$) and good agreement between change in snoring VAS score and change in pAHI. In other words, if a subject's apnea improved after sleep surgery, both pRDI and pAHI were reduced.

Figure 3 shows scatter plots of change in pre- and postoperative apnea VAS score vs. change in pre- and postoperative pRDI and pAHI. We found a high correlation (r = 0.809 for RDI, r = 0.765 for AHI, $p < 0.05$) and good agreement between these values. If a subject's apnea improved after the sleep surgery, both pAHI and pRDI were reduced. In particular, the 7 subjects who did not show improvement in VAS for snoring or apnea also did not show much improvement in pRDI or pAHI.

We also evaluated the change in pre- and postoperative ESS score vs. change in pre- and postoperative pRDI and pAHI (**Figure 4**). We found a high correlation (r = 0.774 for RDI, r = 0.758 for AHI, $p < 0.05$) and high concordance between change in ESS score and pRDI and pAHI values. Again, the pRDI and pAHI values significantly decreased in subjects whose daytime somnolence was improved after the sleep surgery, but neither factor improved in subjects who still complained of daytime somnolence after sleep surgery.

DISCUSSION

In this study, we assessed the surgical results of OSA subjects using the watch-PAT and found that factors such as pRDI, pAHI, lowest oxygen saturation, and valid sleep time that were measured by watch-PAT appear to be well correlated with the improvement in a subject's symptoms and reflect corrected airway narrowing.

The present accepted standard for OSA diagnosis is a full PSG in a sleep laboratory, and an overnight full PSG as a level I study is largely viewed as the most comprehensive. Full PSG involves 16 or more channels monitoring EEG, EKG, EOG, EMG, airflow oximetry, nasal pressure, esophageal pressure, body position, snoring sounds, and rib cage and abdominal movements.[9] Full PSG should be performed in a hospital or sleep laboratory, with a sleep technologist and board certified

Figure 2—Change in pre- and postoperative VAS score for snoring vs. change in pre- and postoperative pRDI ($r = 0.785$, $p < 0.05$, white dot) and change in pre- and postoperative snoring VAS score vs. change in pre- and postoperative pAHI ($r = 0.829$, $p < 0.05$, black dot)

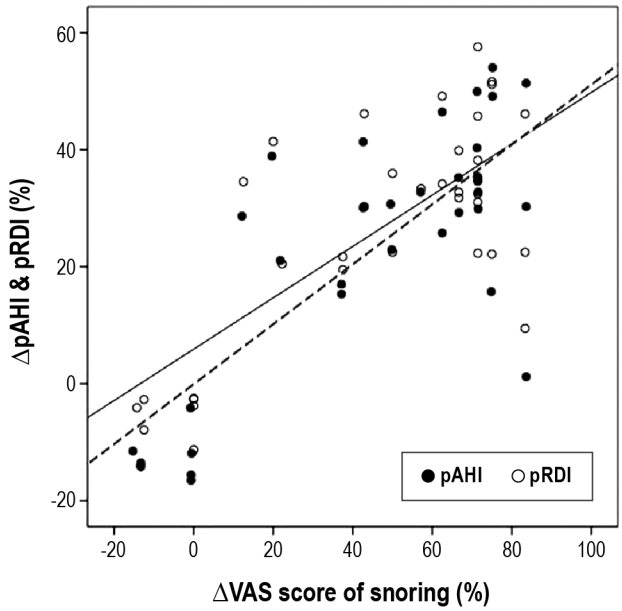


Figure 3—Change in pre- and postoperative apnea VAS score vs. change in pre- and postoperative pRDI ($r = 0.809$, $p < 0.05$, white dot) and change in pre- and postoperative apnea VAS score vs. change in pre- and postoperative pAHI ($r = 0.765$, $p < 0.05$, black dot)

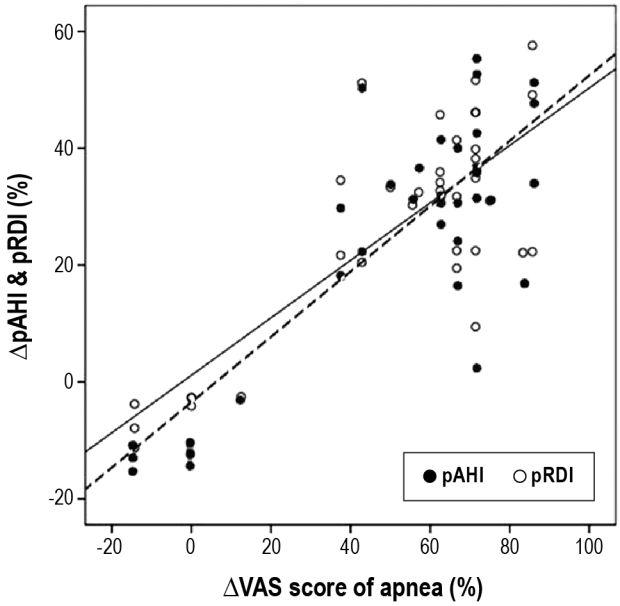
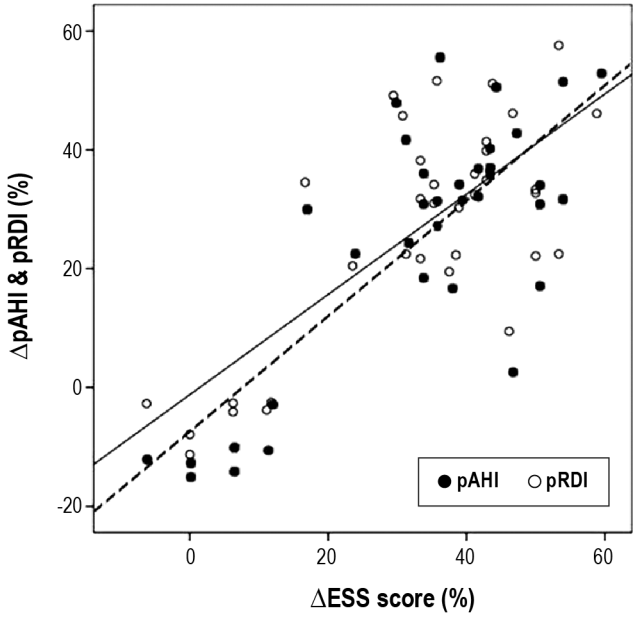


Figure 4—Change in pre- and postoperative ESS score vs. change in pre- and postoperative pRDI correlation ($r = 0.774$, $p < 0.05$, white dot) and change in pre- and postoperative ESS score vs. change in pre- and postoperative pAHI correlation ($r = 0.758$, $p < 0.05$, black dot)



sleep physician needed to score all the PSGs. The cost of such studies is relatively high, and they are carried out in an unfamiliar sleep environment.

Portable PSG units were developed because of several recognized advantages over sleep-laboratory PSG, including sleep in a more familiar and flexible environment, fewer monitor leads, more convenience for patients with respect to transportation, probable reduced sleep disturbance, less technical complexity, and lower cost.[10] The 1994 AASM practice standards ultimately concluded that there were some limitations to portable PSG for OSA assessment, and the efficacy of portable PSG was still controversial. Advances in the diagnosis and treatment of OSA have occurred largely based on data from full PSG, and portable PSG was assumed to not provide better or more reliable diagnosis of OSA or other sleep disordered breathing (SDB). Therefore, the AASM recommends that portable PSG should be used only in conjunction with a comprehensive sleep evaluation and must be supervised by a certified or eligible sleep medicine specialist.[11]

Many portable monitoring devices for the diagnosis of OSA have been tested as an alternative to full PSG. Several studies pronounced the validation of portable PSG for the diagnosis of OSA or accordance with full PSG, and the clinical concordance of AHI, RDI, and oxygen desaturation between portable and full PSG has been suggested.[12,13]

A portable PSG that uses pulsatile arterial tonometry, the watch-PAT might be accurate in identifying moderate-to-severe SDB. The watch-PAT device is unique since it allows for diagnosis of OSA through the detection of episodic vasoconstriction of the digital vascular beds rather than conventional measures of airflow and chest/abdominal excursion such as the PSG.[14] The watch-PAT is a level III sleep study that detects peripheral arterial tonometry, making possible at-home testing. Also,

the accuracy of watch-PAT in the diagnosis of OSA and related sleep factors between watch-PAT and full PSG have been assessed in various studies.[10,15,16] Bar et al. reported that the PAT AHI and PSG AHI were in high concordance with each other across a wide range of AHI values.[16] Similarly, a study performed by Pittman et al. compared PSG scoring data and watch-PAT data and showed a high correlation between PSG AHI and PAT AHI values.[17] Due to the portability and low cost of the watch-PAT, sleep study may be conveniently and efficiently performed prior to and after CPAP therapy.[15] The watch-PAT device is easy to use for home sleep studies, with a low failure rate for single use and with minimal technician time when compared with PSG.[12,18] However, there have been a few studies in which the surgical results assessed after correcting airway narrowing using watch-PAT did not correlate well with the subjects' reported symptoms.

In the present study, we performed a sleep study using a watch-PAT both before and after sleep surgeries in order to diagnosis OSA and also evaluated the effect of surgical correction for airway collapse. We found that the mean values of the watch-PAT-derived parameters, such as pAHI, pRDI, lowest oxygen saturation, and valid sleep time were significantly improved after the sleep surgeries, and the watch-PAT appears to provide useful clinical information about the efficacy of sleep surgery and success or failure in correction for airway collapse.

Twenty-eight subjects were divided into responder groups after sleep surgery and showed an improvement in subjective symptoms such as snoring, apnea, and daytime somnolence. Their postoperative watch-PAT results showed a significant decrease in pAHI and pRDI values. In addition, oxygen saturation and valid sleep time were improved along with their reported subjective symptoms. These data suggest good correlation and agreement between a subject's symptoms and important parameters of the watch-PAT after surgical correction for airway collapse in OSA subjects. In particular, for the seven subjects who reported having no subjective improvement in snoring, apnea, or daytime somnolence, the watch-PAT also showed no significant change in pAHI, pRDI, lowest oxygen saturation, or valid sleep time, resulting in high correlation to the subjects' symptoms. We conclude that the watch-PAT might be a convenient portable device for evaluating surgical results, and the parameters of watch-PAT could compensate for the disadvantages of full PSG.

The present study did not validate the concordance between overnight PSG and the watch-PAT for measuring the sleep factors. However, many studies have reported the good agreement between the two devices,[3-8] and our main goal was to determine the usefulness of the watch-PAT before and after surgical treatment in order to simply diagnosis and assess OSA results rather than focusing on the concordance between the PSG and the watch-PAT.

OSA is a condition that can greatly affect a person's quality of life and may also result in serious medical disease. Therefore, accurate diagnosis and early treatment are essential for OSA patients. The watch-PAT is easy to use for home sleep studies, with a low failure rate and minimal technical effort.[10] The results of watch-PAT can be interpreted more simply than full PSG and provide useful information about the efficacy of sleep surgeries. This study demonstrates that the watch-PAT may be efficiently applied not only to the diagnosis of OSA, but also to accurately assess treatment results of sleep surgeries.

REFERENCES

1. Remmers JE, deGroot WJ, Sauerland EK, Anch AM. Pathogenesis of upper airway occlusion during sleep. *J Appl Physiol* 1978;44:931-8
2. Peppard PE, Young T, Palta M, Skatrud J. Prospective study of the association between sleep-disordered breathing and hypertension. *N Engl J Med* 2000;342:1378-84.
3. Kushida CA, Chang A, Gadkary C, Guillemanault C, Carrillo O, Dement WC. Comparison of actigraphic, polysomnographic, and subjective assessment of sleep parameters in sleep-disordered patients. *Sleep Med* 2001;2:389-96.
4. Rosario IC. Obstructive sleep apnea: A review and update. *Minn Med* 2011;94:44-8.
5. Pillar G, Bar A, Betito M, et al. An automatic ambulatory device for detection of AASM defined arousals from sleep: the WP100. *Sleep Med* 2003;4:207-12.
6. Schnall RP, Shlitner A, Sheffy J, Kedar R, Lavie P. Periodic, profound peripheral vasoconstriction—a new marker of obstructive sleep apnea. *Sleep* 1999;22:939-46
7. Onder NS, Akpinar ME, Yigit O, Gor AP. Watch peripheral arterial tonometry in the diagnosis of obstructive sleep apnea: influence of aging. *Laryngoscope* 2012;122:1409-14.
8. O'Donnell CP, Allan L, Atkinson P, Schwartz AR. The effect of upper airway obstruction and arousal on peripheral arterial tonometry in obstructive sleep apnea. *Am J Respir Crit Care Med* 2002;166:965-71.
9. Kushida CA, Littner MR, Morgenthaler T, et al. Practice parameters for the indications for polysomnography and related procedures: an update for 2005. *Sleep* 2005;28:499-521.
10. Pillar G, Bar A, Shlitner A, Schnall R, Shefy J, Lavie P. Autonomic arousal index: an automated detection based on peripheral arterial tonometry. *Sleep* 2002;25:543-9.
11. Zou D, Grote L, Peker Y, Lindblad U, Hedner J. Validation a portable monitoring device for sleep apnea diagnosis in a population based cohort using synchronized home polysomnography. *Sleep* 2006;26:367-74.
12. JH Choi, EJ Kim, YS Kim, et al. Validation study of portable device for the diagnosis of obstructive sleep apnea according to the new AASM scoring criteria: Watch-PAT 100. *Acta Otolaryngol* 2010;130:838-43.
13. Pang KP, Grourin CG, Terris DJ. A comparison of polysomnography and the Wath-PAT in the diagnosis of obstructive sleep apnea. *Otolaryngol Head Neck Surg* 2007;137:665-68.
14. Penzel T, Kesper K, Pinnow I, Becker HF, Vogelmeier C. Peripheral arterial tonometry, oximetry and actigraphy for ambulatory recording of sleep apnea. *Physiol Meas* 2004;25:1025-36.
15. Ayas NT, Pittman S, MacDonald M, White DP. Assessment of a wrist-worn device in the detection of obstructive sleep apnea. *Sleep Med* 2003;4:435-42.
16. Bar A, Pillar G, Dvir I, Sheffy J, Schnall RP, Lavie P. Evaluation of a portable device based on peripheral arterial tone for unattended home sleep studies. *Chest* 2003;123:695-703.
17. Pittman SD, Ayas NT, MacDonald MM, Malhotra A, Fogel RB, White DP. Using a wrist-worn device based on peripheral arterial tonometry to diagnose obstructive sleep apnea: in-laboratory and ambulatory validation. *Sleep* 2004;27:923-33.
18. Yin M, Miyazaki S, Ishikawa K. Evaluation of type 3 portable monitoring in unattended home setting for suspected sleep apnea: factors that may affect its accuracy. *Otolaryngol Head Neck Surg* 2006;134:204-9.

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DISCLOSURE STATEMENT

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