The Effect of Postural Changes on Spirometric Indices of Upper Airway Obstruction

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Abstract

The spirometric diagnosis of upper airway obstruction is an important non-invasive technique that was validated for the diagnosis of such lesions relying on several indices that were derived from the flow volume loops of patients.

Objectives: Is to find out if postural changes have an effect on spirometric indices of airway obstruction in healthy subjects and if so, does this merit performing the test in supine posture?

Subjects and methods: This study conducted in the department of physiology and medical physics/ Kerbala medical college, in which 17 males aged from 18-19 years (18.53 ± 0.51), had BMI of (22.95 ± 2.11 Kg/M^2), heights of (1.75 ± 0.14 meters) and weights of (70.32 ± 6.34 Kgs) were enrolled. The following spirometric data were measured in two different body positions (erect versus supine): Forced vital capacity (FVC), Forced inspiratory flow at 50% of vital capacity ($FIF_{50\%}$), Forced expiratory flow at 50% of vital capacity ($FEF_{50\%}$), Forced expiratory volume in first second (FEV_1), Forced expiratory volume in first 0.5 second ($FEV_{0.5}$), Peak inspiratory flow (PIF) and Peak expiratory flow (PEF). From these data, the following indices of upper airway obstruction were derived: (FEV_1/ $FEV_{0.5}$, FEV_1/ PEF, $FEF_{50\%}$/ $FIF_{50\%}$, and PEF/PIF). These indices were compared with each other in respect to two body positions.

Results:

1- All the measured inspiratory and expiratory flow rates were significantly lower in supine position ($p < 0.05$).

2- Of the four measured indices of upper airway obstruction, only the FEV_1/PEF ratio increased significantly ($p < 0.05$) by about 27% upon reclining.

الخلاصة

ان تشخيص انسداد المجرى التنفسي العلوي عن طريق فحص وظائف الرئة يعتبر من الطرق التي تمت المصادقة عليها لتشخيص مثل هذه الانسدادات اعتمادا على عدة مؤشرات مستمدة من حلقات التدفق الحجمي للمرضى.

الأهداف: معرفة ما إذا كانت التغيرات الوضعية للجسم لها تأثير على مؤشرات الانسداد لمجرى التنفس والمشتقة من فحص وظائف الرئة وإن كان الأمر كذلك، هل هذا يستحق أداء الاختبار في وضع الاستلقاء على الظهر؟

الطرق والأساليب: أجريت هذه الدراسة في قسم الفسلجة والفيزياء الطبية / كلية الطب/ جامعة كربلاء، حيث ضمت 17 ذكرا تتراوح أعمارهم بين 18- 19 سنة (18.53 ± 0.51)، وكان مؤشر كتلة الجسم (22.95 ± 2.11 كغم/ $م^2$)، وأطوالهم (1.75 ± 0.14 متر) وأوزانهم (70.32 ± 6.34 كلغ). تم قياس البيانات التالية في موقعين مختلفين للجسم (وقوفا مقابل الاستلقاء) تم قياس المؤشرات الأتية: (FVC، $FIF_{50\%}$ ، $FEF_{50\%}$، $FEV_{0.5}$ ، FEV1، FEV ، PIF و PEF). من هذه البيانات، استخلصت المؤشرات التالية: (FEV_1/ PEF FEV_1/ $FEV_{0.5}$, PEF, $FEF_{50\%}$/ $FIF_{50\%}$, PEF/PIF). وتمت مقارنة هذه المؤشرات مع بعضها البعض فيما يتعلق بوضعتي الجسم المختلفتين.

النتائج:

كانت جميع معدلات التدفق الشهيقي والزفيري أقل بأهمية احصائية في وضع الاستلقاء عن مثيلاتها في وضع الوقوف ($p < 0.05$). ومن بين مؤشرات انسداد المجرى التنفسي العلوي الأربعة ، فقط نسبة FEV_1/PEF ازدادت معنويا ($p < 0.05$) بنحو 27٪ عند الاستلقاء.

Keywords: PFT, UAO, FVL, Body posture, and OSAS.

Introduction

Since the early seventies, when Miller *et al* *(1)* and Yernault *et al* *(2)* proposed the first diagnostic criteria for upper airway obstruction (UAO), that were derived from the visual inspection of the flow volume curves (FVCs) obtained by conventional spirometry. Ever since, these criteria underwent validation with respect to other diagnostic techniques used to diagnose UAO such as flexible tracheal fluoroscopy and bronchoscopy *(3)*.

The spirometric diagnosis of obstructive lesions in the upper airways is getting more and more crucial since these lesions may produce respiratory failure *(4)*, and with the advent of endotracheal intubation, there may be laryngotracheal obstruction secondary to this instrumentation, *(5)* therefore, if recognized, many of these lesions are amenable to corrective surgery.

The criteria by which the diagnosis can be made include limitation of inspiratory airflow, an irreversible increase in airway resistance coexisting with normal distribution of inspired gas, and an increase in the resistance in the upper airways *(6)*. Miller and Hyatt *(1)* in their classical papers recognized the flow-volume loop (FVL) as a valuable test for the detection and assessment of upper airway obstruction. The value of the FVL, as opposed to static imaging techniques, lies in the fact that it takes into account the dynamic characteristics of the upper airway, i.e., the changes in caliber that the collapsible parts of the upper airway undergo as a result of the changes in transmural pressure induced by forced inspiratory and forced expiratory maneuvers. The effect of these maneuvers, used for the generation of a FVL, on the caliber of the upper airway and, hence, on the effort-dependent inspiratory and (early) expiratory flow rates is exaggerated in the presence of an upper airway lesion that affects the structural or functional integrity of the upper airway. As a result, the forced FVL is a useful test for the detection of upper airway instability by producing flow oscillations and for detecting frank UAO, as reflected by a flattened FVL contour, reduced effort-dependent inspiratory and expiratory flow rates, and abnormal values for so-called UAO indices *(7)*.

Several studies showed that changes in body posture might be used to further increase the capability of the FVL to detect UAO. Indeed, in two patients with a thyroid goiter, the FVL obtained in the supine posture revealed functional evidence of UAO not present on the FVL obtained in the traditional upright posture *(8)*. However, before recommending recumbent FVLs in patients in whom UAO is suspected, it is necessary to determine the effect of the recumbent posture on the FVL-derived parameters and UAO indices in normal subjects, as reported in this study.

Subjects and methods

This study was conducted in the department of physiology and medical physics/ College of Medicine/ University of Kerbala, from the period of November 2012 to January 2013 where 22 apparently healthy medical students responded actively to the advertisement announced by the department and expressed their willingness to participate in the study. All of the volunteered students were males (none of the females expressed consent for participation, an issue that needs to be addressed). Of the enrolled students, five of them were excluded owing to the following exclusion criteria:

1. Overweight or obesity (BMI > 25 Kg/M^2).
2. Smoking history (recent or past).
3. History of recent chest infection (i.e. within the last month prior to the study).

4. Thoracic or abdominal condition that may limits the procedure of data acquisition.
5. History of bronchial hyper-responsiveness.

For every participant, along with the detailed medical history and relevant medical examination, the following anthropometric data were recorded; the age, weight, height, and BMI. The enrolled participants aged from 18-19 years (18.53 ± 0.51), had BMI of (22.95 ± 2.11 Kg/M^2), heights of (1.75 ± 0.14 meters) and weights of (70.32 ± 6.34 Kgs). Despite the fact that most of the participants were acquainted with the use of spirometer, nevertheless, a detailed explanation of the procedure was given and all of them were instructed to perform rehearsals about the procedure in two different body positions. By using Spirolab-III provided by MIR, Roma, Italy and according to American Thoracic guidelines and standards *(9, 10)*, the following spirometric data were measured FVC, $FIF_{50\%}$, $FEF_{50\%}$, FEV_1, $FEV_{0.5}$, PIF and PEF. Flow volume loops (FVLs) were also obtained. The values recorded as absolute value measured and percentage predicted with respect to their age, weight, height using Udwadia standards. *(11)*

The FVLs and the spirometric data were both obtained in two different body position (*erect and supine*). Randomization of body posture to obtain data from one subject to another was carefully stressed upon, an adjustable cervical collar was used in each one of the two postures to limit the neck flexion and extension, a period of rest of not less than 30 seconds was allowed before repeating any respiratory maneuver to eliminate the effect of fatigue on data collection, and a period of not less than 15 minutes upon shifting from one posture to the other was a mandate. Data collection depends on the best of three attempts in spirometric maneuvers for each participant. *(9, 10)*

Upper airway obstruction was defined based on the following parameters in pulmonary function testing (PFT) *(12, 13)*

1. Forced inspiratory flow at 50 percent of the vital capacity ($FIF_{50\%}$) ≤ 100 L/Min.
2. Ratio of forced expiratory flow at 50 percent of the vital capacity ($FEF_{50\%}$) to the $FIF_{50\%}$ ($FEF_{50\%}/FIF_{50\%}) \geq 1$.
3. Ratio of the forced expiratory volume in one second measured in milliliters to the peak expiratory flow rate in liters per minute ($FEV_1/PEF) \geq 8$ ml/ L/min.
4. Ratio of the forced expired volume in one second to the forced expired volume in 0.5 second ($FEV_1/FEV_{0.5}) \geq$ 1.5.
5. Visual inspection of the flow volume loop (FVL) for flattening or oscillations. *(14)*

Statistical analysis

Statistical analysis was performed using the least significant differences (LSD) post Hoc test to identify the group (s) responsible for statistical differences following student paired t-test, utilizing (SPSS version-16) and (Excel-2010) softwares. All values expressed as Mean ± SD. Results with P value of less than 0.05 considered statistically significant.

Results and discussion

None of the study subjects developed neither a plateau nor oscillations in their maximal inspiratory and expiratory flow volume curves after visual inspection of their FVLs.

- *Regarding inspiratory and expiratory flow rates:*

The inspiratory and expiratory spirometric data whether effort related or not, were all decreased upon assuming supine posture. Table-1 shows that each of the measured maximal inspiratory and expiratory flow rates (i.e. FVC, FEV_1, $FEV_{0.5}$, PEF, $FEF_{50\%}$, $FIF_{50\%}$, and PIF) decreased significantly in the supine compared with the erect posture ($p < 0.05$).

Table - 1: the changes in the inspiratory and expiratory flow rates after changing from erect to supine posture.

Parameter	***Unit***	***Posture***		***Change percentage***
		Erect	***Supine***	
FVC	L	5.09 ± *1.1*	4.72 ± *1.07*	– 7.27 % †
FEV$_1$	L	4.42 ± *0.82*	4.13 ± *0.8*	– 6.56 %†
FEV$_{0.5}$	L	3.38 ± *0.61*	3.15 ± *0.74*	– 6.8 % †
PEF	L/s	10.09 ± *2.19*	9.14 ± *2.02*	– 9.42 % †
FEF$_{50\%}$	L/s	5.8 ± *1.39*	5.16 ± *0.55*	– 11.03 % †
FIF$_{50\%}$	L/s	7.28 ±*1.72*	6.61 ± *1.13*	– 9.2 % †
PIF	L/s	7.24 ±*1.57*	7.01 ± *1.02*	– 3.18 % †

† Significant ($p < 0.05$)

* All data are expressed as mean ± *SD* unless mentioned elsewise.

These results are consistent with those of Lalloo *et al* ***(15)*** who concluded that all spirometric indices are higher upon standing. The same results were reported by Chen *et al* ***(16)*** who reported that the vital capacity of an able-bodied subject was enhanced in the standing posture, a result which Druz and Sharp ***(17)*** attributed to an increase in the activation external intercostal muscles and the diaphragm in the upright posture, where owing to the stiffened abdomen, the activated intercostal muscles act to move the ribcage more effectively and promote ribcage expansion. In addition, in supine postures, the diaphragm aids in providing greater compliance with the abdomen over the ribcage. ***(18)***

In this study, the reduction in the forced inspiratory and expiratory flow rates cannot be attributed to respiratory muscles fatiguing since, by design, the order in which the two body postures were randomized, furthermore, the subjects were allowed to rest between the two body postures. One explanation for this finding is an increase in the resistance of the upper airway on assuming supine postures. It has indeed been shown that in normal subjects ***(19, 20)*** as well as in patients with obstructive sleep apnea syndrome (OSAS), ***(21)*** pharyngeal size decreases significantly in the supine posture compared with the upright posture, and thus limiting the airflow rates. This occurs independently of posture-related changes in lung volume (functional residual capacity) ***(19)*** and is attributed to gravitational forces acting on the tongue and soft palate. ***(20)***

Differences in the position of the neck may, by altering the longitudinal tension on the trachea and hence its stiffness, affect maximal expiratory flow rates. ***(17)*** However, this was carefully avoided by keeping the relation of the head and neck to the trunk constant in the two body postures by using an adjustable cervical collar.

Finally, the most probable explanation for the supine-induced changes in flow rates is a decrease in lung volume. Recumbency produces a significant reduction in total lung capacity, residual volume, and vital capacity; these changes are small in the order of 10 % or less ***(23)***, (*in this study it was up to 7.27 %*) and are related mainly to an increase in intrathoracic blood volume. ***(24)*** Since airway caliber is clearly dependent on lung volume, so it is to be expected that flow rates also decrease with decreasing lung volume in the supine position.

Table-2 shows that the four spirometric indices of airway obstruction have changed upon assuming supine position from erect position but, a part from the significant increase in FEV$_1$/ PEF ratio, these changes were insignificant (P < 0.05).

Table - 2: the changes in airway obstruction indices after changing from erect to supine posture.

Parameter	***Unit***	***Posture***		***Change percentage***	***Confidence interval at 95%***	
		Erect	***Supine***		***Erect***	***Supine***
$FEV_1/ FEV_{0.5}$	-	1.33 ± *0.05*	1.45 ± *0.04*	+ 12 %	± 0.02	± 0.02
FEV_1/ PEF	mL/L/Min	6.34 ± *0.13*	6.61 ± *0.22*	+ 27 % †	± 0.06	± 0.10
$FEF_{50\%}/ FIF_{50\%}$	-	0.80 ± *0.11*	0.98 ± *0.10*	+ 16 %	± 0.05	± 0.05
PEF/PIF	-	1.39 ± *0.31*	1.45 ± *0.29*	+ 6 %	± 0.15	± 0.14

† Significant ($p < 0.05$)

* All data are expressed as mean ± *SD* unless mentioned elsewise.

- Regarding UAO indices

These results are inconsistent with the findings of Masumi *et al* (25) who examined the effect of reclining on $FEF_{50\%}/ FIF_{50\%}$ ratio (the only parameter they measured) and reported that upon reclining, there will be a significant decrease in this ratio in nine non-obese normal subjects. These significant differences presumably resulted from gravity causing an approximation of the tongue and soft palate relative to the posterior unmovable pharyngeal wall. The altered anatomic relationship induces neurosensory stimulation that influences the motor tone and collapsibility of the airway (26).

All the four indices reported in this study have a mean value consistent with those reported by similar studies. (26, 27) Although all measured inspiratory and expiratory flow rates decreased significantly in the supine posture compared with the erect posture, only one of the UAO indices derived from these flow rates changed significantly, namely (the FEV_1/ PEF ratio), as shown in figure-1.

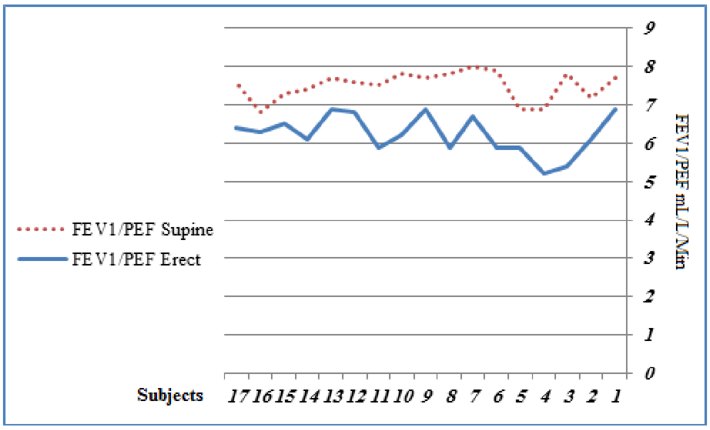

Figure-1: the effect of changing posture on the FEV1/PEF ratio in the 17 study subjects.

This indicates that in supine postures, the PEF decreased proportionally more than the FEV_1, suggesting that upper airway resistance is higher in supine postures than in the erect posture. In support of this speculation, Behrakis *et al* (28) found pulmonary flow resistance to be increased in 10 healthy young adults when shifting from a sitting to recumbent posture. Since Vincent *et al* (29) showed that lower airways resistance increases with decreasing lung volume, Behrakis *et al* (28) reasoned that the lack of change in pulmonary flow resistance when shifting from the erect to the supine posture suggested greater upper airways resistance. This greater upper airway resistance, then, would affect the flow rates at high lung volume (such as the PEF) to a greater extent than the less effort-dependent flow rates (such as the FEV_1). Hence, the FEV_1/PEF ratio can be expected to be higher in the supine posture than in the erect posture (*in this study the* FEV_1/PEF *ratio increased by + 27%*). Indeed, flow rates at high lung volume, such as the PEF, are more strongly affected by changes in upper airway resistance than is the FEV_1 as shown by Miller and Hyatt. (1, 30)

Nahmias and Karetzy, (24) reported that an increased proportion of (OSAS) patients showed flattening of the maximal inspiratory flow volume curve (i.e., a reduction in forced inspiratory flow rates) when tested in the supine posture. In accordance with Shore and Millman, (31) they concluded that addition of supine FVLs increases the sensitivity of the FVL for detecting UAO in patients with the OSAS. Hence, the indices commonly used to detect UAO in the erect posture can also be used to indicate the absence or presence of UAO in the supine postures.

Conclusions and recommendations

In conclusion, this study had shown that measurement of FVLs is feasible in supine postures. The recumbency-related changes in UAO indices reported here might increase its sensitivity for detecting an upper airway lesion or assessing its effect on upper airway patency.

Recommending such an assessment might be useful in decision-making, e.g., in deciding whether a patient with a goiter should undergo surgery, to document the return of integrity of the upper airway following goiter surgery, after weight loss in obese patients with OSAS.

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