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## Original Article

# Features of trunk muscle weakness in patients with ankylosing spondylitis: A cross-sectional study

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## ABSTRACT

**Background:** Ankylosing spondylitis (AS) is an inflammatory autoimmune disorder that manifested with sacroiliitis at its early stage and developed extensive inflammation with syndesmophytes of the lumbar, thoracic and cervical spines at its later stage. In the present study, we characterized the trunk isometric strength in patients with AS with different disease severity, defined by the radiological images.

**Methods:** In a cross-sectional study conducted in a university-affiliated hospital, thirty-eight male AS patients (23 in the early AS group whose radiological findings showed no syndesmophyte, Modified Stoke Ankylosing Spinal Score (m-SASSS <3); and 15 in the syndesmophyte group, m-SASSS ≥24), and 22 healthy controls were recruited. All subjects received assessments of maximum isometric strength of trunk flexor and extensor muscles at a variety of trunk postures measured by an isokinetic device.

**Results:** Under all examined trunk postures, the syndesmophyte AS patient group had the lowest isometric trunk muscle strength among the three groups. The flexion/extension ratio, defined by the ratio between isometric trunk flexor and extensor strengths, was highest among the three groups.

**Conclusions:** Trunk muscle strength significantly decreases in patients with syndesmophyte AS. The decrease of trunk muscle is inhomogeneous, which is more profound in extensor than in flexor muscles.

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## At a glance commentary

### Scientific background on the subject

Ankylosing spondylitis (AS) is an inflammatory autoimmune disorder that manifested with sacroiliitis at its early stage and developed extensive inflammation with syndesmophytes of the spine at its later stage. It remains unclear regarding the trunk isometric strength in patients with AS with different disease severity.

### What this study adds to the field

Under all examined trunk postures, trunk muscle strength decreases in ankylosing spondylitis patients with syndesmophytes. The decrease of trunk muscle is inhomogeneous, which is more profound in extensor than in flexor muscles.

Ankylosing spondylitis (AS) is an inflammatory autoimmune disorder [1] that manifests with sacroiliitis at its early stage and developed extensive inflammation of the lumbar, thoracic and cervical spines of severe form [2,3], causing spinal ankylosis (“bamboo” spine), kyphotic deformity, and an abnormal stooping posture on standing and walking at its later stage [4]. The unique structural changes of spine with syndesmophyte formation and ankylosis are the primary causes of early severe working disability and impaired health-related quality of life [1,5].

AS causes muscle wasting as researchers have reported reduced muscle strength of upper and lower limbs in patients with AS. For patients with AS, computed tomography scan showed decreased overall muscle mass and fibrosis in the quadriceps muscle [6–9]. The strength of trunk muscle has important functional implications for the elderly and for patients with spine disorders. For example, trunk muscle strength has been shown to predict the quality of life (QOL) in middle-aged and elderly males and postmenopausal, osteoporotic females [10,11].

The thoracic/lumbar angle ratio (T/L ratio) increases with aging, further causing the decrease of lumbar lordosis. The decompensated sagittal trunk balance, lumbar lordosis posture, and decreased back muscle strength had been reported to influence QOL in the elderly. Specifically, impaired ROM and strength usually occur altogether and thus cause impaired quality of life, posture, balance, and gait [12]. Trunk muscle strength correlates to locomotive ability in community living elderly [13,14] and the strength of trunk extensors correlates to spinal curve deformity in elderly osteoporotic women [12]. To the best of our knowledge, the effect of impaired balance on quality of life has not been established. In this study, we thought it is important to study back muscle strength given its importance in the studies for the elderly.

Several factors could contribute to trunk muscle weakness in patients with AS, including general cachexia induced by chronic

systemic inflammation [15], fibrosis of paraspinal muscles, back pain with reflex inhibition of back muscles, fused spine with kyphotic posture, long-term immobilization with joints stiffness [16] and deconditioning. Gordon et al. noticed morphological atrophy of the paraspinal muscles, such as the erector spinae and multifidi at L3-L4 levels [17]. However, to the best of our knowledge, no study has examined the trunk muscle strength in patients with AS even though this understanding is clearly fundamental for functional and interventional purposes. Furthermore, it is possible that, following the progression of AS, the patient's trunk muscle strength will deteriorate correspondingly, as the aforementioned factors tend to be more severe in advanced stages of AS.

In the present study, we used an isokinetic trunk testing system to measure isometric muscle strength in trunk flexors and extensors, respectively, in patients with and without syndesmophytes of AS categorized by their radiological findings and in normal control subjects. The recruitment of patients with different disease groups allows for understanding of trunk muscle strength in disease progression. Kinematic studies showed that different trunk angles will recruit different muscle groups [18] so that a comprehensive trunk muscle assessment needs to include a series of trunk angles. For example, the relative recruitment of abdominal muscle, including transversus abdominis, obliquus internus and externus abdominis, and rectus abdominis differs among trunk and pelvic postures [19]. From a therapeutic point of view, it is also important to know the weak muscle groups so that therapeutic exercise can be correctly prescribed by the physician. To this end, we assumed that muscle power will be different across trunk postures in both healthy and patient groups and we tested their muscle strength at various trunk postures to cover a wide spectrum of functional scenarios.

Finally, the balance between muscle strength in the flexor and extensor muscle is a major issue of rehabilitation for patients with spine disease. The trunk is considered as a hydraulic stability system that needs coordinated muscle strength between flexors and extensors. For example, patients with spondylolisthesis tend to have relatively weak trunk flexor muscles so that training for flexors will improve their spine stability and clinical symptoms. Again, for patients with AS, no studies have yet addressed this issue so that this study will also evaluate the relative muscle strength between trunk flexors and extensors. We hypothesized that patients with AS have relatively weak muscle strength as compared with their healthy counterparts and their imbalance between trunk flexors and extensors will be substantial. Also, patients with a severe radiological stage will have a more profound loss of trunk muscle strength.

## Methods

### Subjects

Thirty-eight male patients who were (1) fulfilled the diagnosis of AS by the New York criteria [20], (2) in a non-active disease state and (3) with no motion-limited back pain symptoms were recruited from the Rheumatology and Immunology Clinic in a university-affiliated medical center. Due to the clinical characters and presentations of AS are wide ranged in

**Table 1** The demographics of the subjects.

Group	Syndesmophyte AS (n = 15)	Early AS (n = 23)	Normal control (n = 22)	p value	Post-hoc
Age (year)	38.0 ± 5.0	31.4 ± 8.2	30.4 ± 4.9	<0.01**	ab**, ac**
Body height (cm)	166.1 ± 5.9	169.6 ± 6.6	170.2 ± 5.6	0.1	
Body weight (kg)	61.7 ± 9.8	63.8 ± 8.0	67.7 ± 7.5	0.09	
Gender (M/F)	15/0	23/0	22/0		

\*\**p* < 0.01; AS: ankylosing spondylitis.

Abbreviations: ab: significant difference between syndesmophyte and early AS groups; ac: significant difference between syndesmophyte and normal groups.

variety, we recruited male patients only in order to maintain relatively homogenous subject characteristics. All patients received standard radiographs for lumbar, thoracic and cervical spines, and pelvis with bilateral hip joints. The clinical and radiographic results were reviewed by both of the two experienced rheumatologists (Dr. Ho and Chen) and only those showing bilateral sacroiliitis without hip involvement were included for the present study. We also recruited 22 healthy male subjects serving as the control group (Table 1). The criteria are healthy subjects having no low back pain with the recent 3 months, having no major disease (including diabetes mellitus, hypertension, or rheumatoid disease), and having a active lifestyle.

Across the patient and healthy groups, subjects with any neuropsychological disease, injury of back or spine, previous back or spinal surgery, limitation in range of motion of the lower extremities, or lower extremity weakness (manual muscle testing less than 5) were excluded. None of the patients used medications that affected the central or peripheral nervous systems or muscle function, with the exceptions of using non-steroidal anti-inflammatory drugs and disease modifying anti-rheumatic drugs. No patients participated in any systematic aerobic or muscular strength training activities. This study was specifically approved by the institutional review board of human clinical trial committee that conforms to Helsinki Declaration, and each subject signed a written informed consent statement before participation.

According to the radiological findings in Modified Stoke Ankylosing Spinal Score (m-SASSS) [21,22], two disease severity groups of AS patients were recruited, including (1) the early AS group and (2) syndesmophyte AS groups. Specifically, patients in the early AS group (n = 23) had a presentation of bilateral sacroiliitis only without syndesmophytes (m-SASSS <3), while those in the syndesmophyte AS group (n = 15) presented with bilateral sacroiliitis and syndesmophytes of spine, defined by the findings that the entire spine showed bridging marginal syndesmophytes (m-SASSS ≥24).

#### Apparatus and the procedures for testing isometric muscle strength

We measured the subjects' trunk isometric muscle strength using the Kin-Com<sup>1</sup> trunk testing system. The system received regular calibration for its velocity, torque baseline, lever arm length and position following the manufacturer's standard calibration procedures. Each subject performed three

maximum flexor isometric contractions at four trunk flexion postures (0°, 5°, 10°, or 15°), and three maximum back extensor isometric contractions at three trunk extension postures (0°, 5°, or 10°). The subjects performed three isometric trials for each trunk position and movement direction conditions. The peak forces (unit: % of body weight) of the three trials were averaged to yield the mean isometric strength. All test procedures were performed by the same physiotherapist to aid measurement reliability. To ensure adequate warm-up and to minimize the possibility that the musculoskeletal stiffness hinders the performance of muscle strength, each subject was applied with a hot pack to his middle and lower back before the test for 15 minutes and then performed warm-up for five minutes and flexibility exercise for another five minutes.

The subject was examined in a seated position on an adjustable seat of the Kin-Com trunk testing system with his lower body stabilized (Fig. 1). The rotation axis of dynamometer was aligned at the iliac crest level. The axis pad was positioned in the midline of the trunk, and bilateral curved anterior pelvis pads were pushed backward on the pelvis so

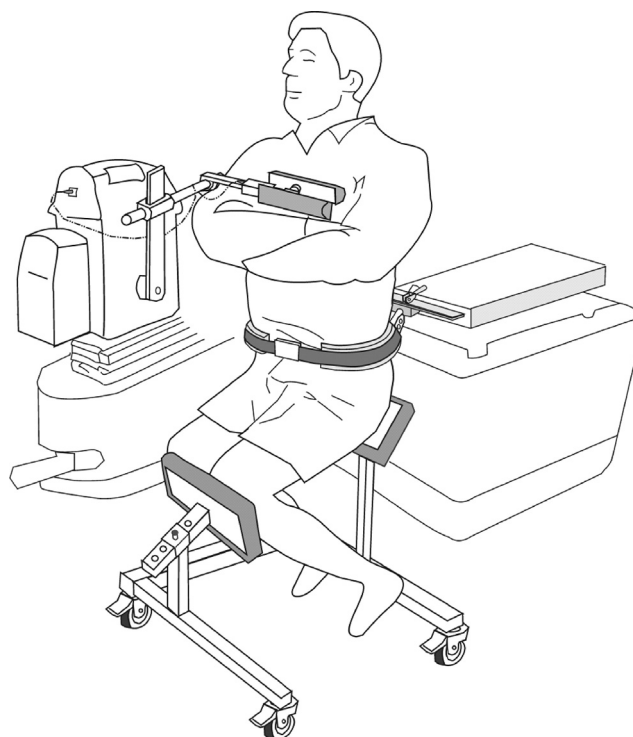


Fig. 1 The set-up of trunk isometric muscle strength measurement.

<sup>1</sup> Suppliers' list: Kin-Com system: Chattanooga Group, Inc, TN, USA.

**Table 2 Comparison of isometric muscle strength among the three groups at different trunk postures. The data is presented with mean  $\pm$  s.d. (%bw).**

Posture	Syndesmophyte AS (n = 15)	Early AS (n = 23)	Normal control (n = 22)	p value	Post-hoc
<b>Extension</b>					
0°	66.8 $\pm$ 20.6	94.4 $\pm$ 22.5	104.6 $\pm$ 17.7	group: $p < 0.001^{***}$	ab ac, bc
5°	60.6 $\pm$ 18.1	91.9 $\pm$ 23.2	99.8 $\pm$ 16.7	posture: $p < 0.001^{***}$	I-II, I-III, II-III
10°	49.9 $\pm$ 17.7	86.0 $\pm$ 23.4	94.7 $\pm$ 17.2	interaction: 0.01*	
<b>Flexion</b>					
0°	45.5 $\pm$ 10.4	62.0 $\pm$ 16.4	72.3 $\pm$ 12.7	group: $p < 0.001^{***}$	ab ac, bc
5°	46.0 $\pm$ 10.6	63.8 $\pm$ 15.6	71.1 $\pm$ 12.9	posture: $p < 0.01^{**}$	II-IV, III-IV
10°	44.4 $\pm$ 10.4	64.0 $\pm$ 14.9	71.0 $\pm$ 13.3	interaction: 0.02*	
15°	43.3 $\pm$ 9.1	62.7 $\pm$ 15.1	69.4 $\pm$ 13.2		

%bw: percentage of body weight; \*,  $p < 0.05$ ; \*\*,  $p < 0.01$ , \*\*\*  $p < 0.001$ .  
 Abbreviations: ab: syndesmophyte AS vs. early AS groups; ac: syndesmophyte AS vs. normal control groups; bc: early AS vs. normal control groups.  
 I-II: angle 0° vs. angle 5°, I-III: angle 0° vs. angle 10°; II-III: angle 5° vs. 10°; II-IV: angle 5° vs. angle 15°; III-IV: angle 10° vs. angle 15°.

that the back was firmly tightened into the axis pad for pelvis stabilization. Knees joints were stabilized at a flexion position by a seat pad placed behind the gluteal area/upper thighs and a booster was placed on the anterior tibia. The seated posture was similar to that used previously for assessing trunk muscle strength for patients with chronic low back pain [23] except that we used a booster to provide additional knee support.

Subjects were first instructed to practice two submaximal and three maximal isometric trunk flexion and extension contractions, respectively, at the 0° trunk flexion posture (neutral trunk posture) to get familiar with the apparatus. Each trial lasted for 5 seconds in which the subjects built up strength in the first two seconds and then continued its maximal contraction for the remaining seconds. A 10-second rest was given between contractions, and a 3-minute break between angles. Furthermore, subjects were instructed to avoid explosive contractions. The visual feedback, a visual display providing a graphic representation of their isometric strength, and standardized verbal encouragement ("harder, harder, harder") were provided for facilitating maximal contraction. All patients were able to perform the whole examination without aggravation of back pain. Subjects were randomized to perform the test in one of the two sequences: (1) flexion movement at 0°, 5°, 10° and, 15° of trunk flexion posture; extension movement at 0°, 5°, and 10° of trunk extension posture; or (2) extension movement at 0°, 5°, and 10° of trunk extension posture; flexion movement at 0°, 5°, 10°, and 15° of trunk flexion posture. We performed assessment at four trunk flexion postures but at only three trunk extension postures because flexion postures are relative easy and comfortable than extension postures. To gauge the force ratio between extension and flexion at different trunk postures, including at 0°, 5°, and 10° postures, we computed the flexion/extension (F/E) ratio, defined by the ratio between isometric trunk flexor and extensor strengths.

### Statistical analysis

Demographic data, including age, body height and body weight between the three groups were compared using analysis of variance (ANOVA). In case of significance, Tukey's post-

hoc test was used to determine the significance of differences between group pairs. Two-way ANOVA was used for repeated measures with trunk flexion strength at flexion posture (0°, 5°, 10°, or 15°) and trunk extension strength at extension posture (0°, 5°, 10°), and F/E ratio at three postures (0°, 5°, 10°), respectively. In this two-way ANOVA model, the trunk posture was the within-subject factor and group (early AS, syndesmophyte AS, and control groups) was the between-subject factor. A main effect by Bonferroni was used for post hoc comparisons between trunk postures, and a Tukey test was used for post hoc comparisons between groups. An alpha value less than 0.05 was considered statistically significant.

## Results

### Subject demographics

The comparison of demographic data among the three groups showed that body height was comparable among three groups. However, significant differences in age ( $F_{2,57} = 7.16$ ,  $p = 0.002$ ) between the syndesmophyte AS and other two groups, but not between the early and syndesmophyte AS groups were observed. The three groups did not differ in their body weight ( $F_{2,57} = 2.56$ ,  $p = 0.09$ ) or body height ( $F_{2,57} = 2.37$ ,  $p = 0.1$ ) (Table 1).

### Trunk extension muscle strength

The ANOVA demonstrated that extensor trunk muscle strength differed among groups ( $F_{2,56} = 14.57$ ,  $p < 0.001$ ) and among extension postures ( $F_{2,112} = 4.13$ ,  $p = 0.019$ ). Also, interaction effects were observed between group and trunk extension posture ( $F_{4,112} = 4.04$ ,  $p = 0.004$ ). Post-hoc analysis indicated that trunk muscle strength in the syndesmophyte group was lower than that in the other two groups. Also, extensor trunk muscle decreased in more extended postures. For the interaction effect, we found that extension muscle strengths did not differ among three groups at 0° or 5° extension postures, but extension muscle strengths was lower for the syndesmophyte group as compared to the other two groups at the 10° extension posture ( $p < 0.01$ ) (Table 2).

### Trunk flexion muscle strength

For trunk flexion strength, the ANOVA showed that muscle strength differed among the three groups ( $F_{2,56} = 12.55$ ,  $p < 0.001$ ), but did not differ among flexion postures ( $F_{3,168} = 0.43$ ,  $p = 0.74$ ). Post-hoc analysis indicated that the syndesmophyte group had lower trunk flexion muscle strength than those of other groups (Table 2). For trunk flexion strength, no interaction effect was found between group and posture ( $F_{6,168} = 2.13$ ,  $p = 0.052$ ).

### The F/E ratio

The ANOVA showed that the F/E ratio differed among the three groups ( $F_{2,56} = 4.82$ ,  $p = 0.012$ ) (Fig. 2). Also, interaction effect was observed between group and trunk posture ( $F_{4,112} = 8.24$ ,  $p < 0.001$ ). Post-hoc analysis showed that F/E ratio was higher in the syndesmophyte group than the other two groups. For the interaction effect, we found that F/E ratio did not differ among the three groups at 0° or 5° postures, but F/E ratio was significantly higher at 10° posture for the syndesmophyte group as compared to the other two groups ( $p < 0.01$ ).

## Discussion

The present study demonstrated that trunk muscle strength deteriorates as AS progresses. First, trunk muscle strength in patients with syndesmophyte decreased both in extension and flexion directions. Second, the aforementioned decrease of trunk muscle strength existed in all trunk postures on the flexion-extension degree of freedom. Third, the imbalance of trunk extension and flexion trunk muscle forces gauged by F/E ratio was observed in patients with syndesmophyte AS.

Even though novel biological agents have been applied in patients with early disease stages, such as those with non-radiographic axial spondyloarthritis [24], traditional therapeutic exercises are still crucial in the management of AS [25–27]. This current study supports this scenario. Studies for patients with chronic low back pain have indicated the benefits of the increase of trunk muscle strength induced by trunk

strengthening exercise [18]. Regarding patient with AS, the recommended exercise programs include general fitness, flexibility, and functional training [28–31], but no previous research has specifically targeted the use of trunk muscle training. Conventional AS rehabilitation programs focus on improving physical functioning and maintaining posture through mobility, strengthening, ROM and stretching exercises, targeting on the biomechanical, mobility and postural changes caused by AS [18]. For example, Pilates, an exercise that highlights trunk muscle training, has been shown to improve spinal resilience and mobility, it also as a safe method to improve physical capacity in patients with AS, indicating the importance of trunk muscle strengthening for these AS patients [18]. Although, the present study did not test the exercise training effects on trunk muscle, but we proposed a method for measuring trunk muscle strength which could be applied in the detection of patients with weak trunk muscles and to quantify the outcome of trunk strengthening programs. Our findings suggest that patients with AS have a similar pattern of trunk muscle strength loss to those with chronic low back pain or spinal fusion surgery. In these other conditions, trunk extensor muscle strength decreases with a higher magnitude than the trunk flexion muscle strength, as demonstrated by isometric and isokinetic measurements [32–34]. It has been postulated that chronic low back pain leads to weakness of trunk extensor muscles caused by pain-induced reflex inhibition while spinal fusion surgery causes both reflex inhibition and extension limitation of the trunk muscles [32,34]. Therefore, a strengthening program that focuses more on the extensor muscles might correct the pathological increase of F/E trunk muscle strength ratio, thus possibly inducing better trunk functions in these patients.

AS induces chronic inflammation that mainly affects axial joints and may cause limitations in spinal mobility. As the disease progresses, the changes in the vertebrae will result in typical kyphotic posture [15]. The increase of F/E trunk muscle strength ratio observed in this study might be accounted for by the fact that a gradual kyphotic posture will induce more prominent weakness in the extensor muscles by prolonged overstretching. On the other hand, patients in early stages of AS present with bilateral sacroiliitis without syndesmophyte, and those in late stages of AS present with fixed flexion kyphotic posture with trunk flexor muscles in a short relaxed position [4]. Moreover, part of the loss of trunk muscle strength in patients with AS could also be explained by cachexia caused by general inflammation [15] or local inflammation [3,35,36].

Patients with AS showed decreased muscle mass in their paraspinal, gluteal, and quadriceps muscles [9,37]. Moreover, muscle biopsy of paraspinal muscles found fibrotic changes in patients with AS [7]. Simmons et al. reported that AS patients with severe spinal deformity had remarkable atrophy of Type I and II muscle fibers along with small, scattered sharp angular fibers, and core or targetoid fibers [38]. Accordingly, we suggested that future studies will examine the change of trunk muscles in patients with AS so as to characterize the changes of trunk extensor and flexor muscles in different stages of AS. Moreover, it would be interesting to observe the correspondence among muscle strength, disease severity, muscle morphology and pathological findings.

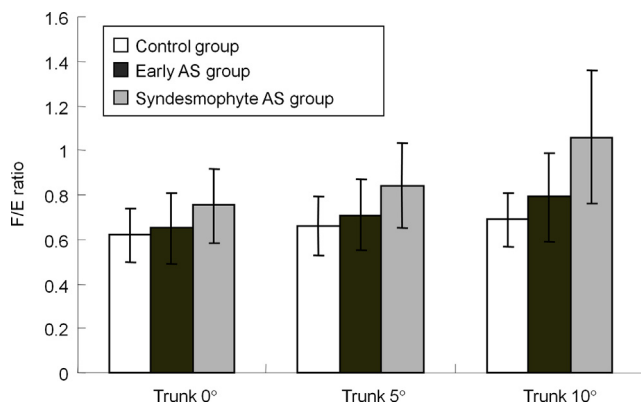


Fig. 2 Comparison of F/E ratio among the three groups at different trunk postures, including 0° (neutral), 5° and 10° postures. Abbreviation used: AS: ankylosis spondylitis.

## Study limitations

A special concern in the present study is that severe AS patients could have osteoporotic and ankylosed spines, having a tendency for spinal fracture upon trivial trauma [39]. Thus, the isometric contractions that we used were specifically designed for patients with AS for the following reasons. First, high angular velocity experienced in isokinetic trunk muscle strength test are not feasible for patients with AS. However, isokinetic and isometric muscle power measurement methods are equally effective for measurement of trunk muscle strength and rehabilitation outcome as demonstrated in patients with chronic low back pain [40]. Second, we only measured sagittal flexion and extension trunk muscle strength, instead of testing trunk muscle strength at other degree of freedoms, such as lateral bending or rotation, because of the mechanical limitations in patients with advanced stage AS. However, the isometric peak force of trunk extension in AS patients was reduced with increasing extension angle, similar to that of normal subjects [37]. Third, another potential limitation is the underestimation of the absolute muscle forces. In the present study, the subjects had several familiarization contractions before the real measurement, but, however, the familiarization contractions could have induced fatigue before the real measurements. It would be better if the familiarization was done a different day before the real measurements were made. Fourth, even though we already provided rest time and breaks between trials, muscle fatigue could occur after repetitive movements. Finally, reliability of trunk muscle strength evaluation is still under examination [23,41,42]. Actually, its reliability is more certain in healthy individuals, but some studies for patients with low back pain revealed conflicting results [43,44]. The present study did not conduct a reliability test so that the statistic features of the present method of isometric muscle strength evaluation still need a more comprehensive analysis. Specifically, its test-retest reliability, norm in healthy subjects of different age groups and clinical noticeable difference need to be carefully characterized before it could be applied in clinical settings. However, this is cross-sectional study of trunk muscle strength in different severity of AS, further studies with longitudinal followed-up are necessary.

## Ethical approval

Institutional Review Board of Chang Gung Medical Foundation No.99-0818B.

## Conflicts of interest

The authors declare no financial support or other benefits from commercial sources for the work reported on in the manuscript, or any other financial interests that any of the authors may have, which could create a potential conflict of interest or the appearance of a conflict of interest with regard to the work.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.bj.2019.01.001>.

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