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The Spine Journal 000 (2020) 1−7

THE SPINE JOURNAL

Clinical Study

Cost-effectiveness of surgical treatment of adult spinal deformity: comparison of posterior-only versus anteroposterior approach

Yoji Ogura, MD[a,*], Jeffrey L. Gum, MD[a], Richard A. Hostin, MD[b], Chessie Robinson, MPH[c], Christopher P. Ames, MD[d], Steven D. Glassman, MD[a], Douglas C. Burton, MD[e], R. Shay Bess, MD[f], Christopher I. Shaffrey, MD[g], Justin S. Smith, MD, PhD[h], Samrat Yeramaneni, MBBS, PhD[i], Virginie F. Lafage, PhD[j], Themistocles Protopsaltis, MD[k], Peter G. Passias, MD[k], Frank J. Schwab, MD[j], Leah Y. Carreon, MD, MSc[a], International Spine Study Group (ISSG)

[a] *Norton Leatherman Spine Center, 210 East Gray Street, Suite 900, Louisville, KY 40204, USA*
[b] *Department of Orthopaedic Surgery, Baylor Scoliosis Center, Dallas, TX 75093, USA*
[c] *Center for Clinical Effectiveness, Baylor Scott & White Health, Dallas, TX 75206, USA*
[d] *Department of Neurological Surgery, University of California, San Francisco, San Francisco, CA, USA*
[e] *Department of Orthopaedic Surgery, University of Kansas Medical Center, Kansas City, KS 66160, USA*
[f] *Denver International Spine Clinic, Presbyterian St. Luke's Medical Center, Denver, CO 80218, USA*
[g] *Department of Neurosurgery, Duke University School of Medicine, 40 Duke Medicine Circle Clinic 1B/1C, Durham, NC 27710, USA*
[h] *Department of Neurosurgery, University of Virginia Health System, Charlottesville, VA 22903, USA*
[i] *Center for Clinical Effectiveness, Baylor Scott & White Health, 8080 N. Central Expressway, Dallas, TX, 75206, USA*
[j] *Department of Orthopaedic Surgery, Hospital for Special Surgery, New York, NY 10021, USA*
[k] *Department of Orthopaedics, NYU Hospital for Joint Diseases, New York, New York*

Received 20 August 2019; revised 31 March 2020; accepted 31 March 2020

FDA device/drug status: Not applicable

Author disclosures: ***YO:*** Nothing to disclose. ***JLG:*** Royalties: Acuity (C); Consulting: Medtronic (C), DePuy, Alphatec, Stryker (B), Acuity (C), K2M (C), NuVasive (C); Research Support (Investigator Salary, Staff/Materials): Pfizer (C). ***RAH:*** Consulting: DePuy (B). ***CR:*** Nothing to disclose. ***CPA:*** Royalties**:** Stryker (F), Biomet Zimmer Spine (C), DePuy Synthes (F), Nuvasive (B), Next Orthosurgical (F), K2M, Medicrea (B). ***SDG:*** Royalties: Medtronic (H); Consulting: Medtronic (F). ***DCB:*** Royalties: DePuy Spine (C), Consulting: DePuy Spine (B). ***RSB:*** Grant: depuy spine (B), k2m (F), nuvasive (F). ***CIS:*** Grant: ISSGF (E), NACTIN (F); Royalties: Medtronic (H), Nuvasive (H), ZimmerBiomet (F); Stock Ownership: Nuvasive (H); Consulting: DePuy Synthes (B), Medtronic (C), Seimens (B). ***JSS:*** Grant: DePuy Synthes/ISSG (C). Royalties: Zimmer Biomet (F), NuVasive (A); Stock Ownership: Alphatec (E); Consulting: Zimmer Biomet (E), Nuvasive (Money Paid to You), Cerapedics (Money Paid to You), AlloSource (B); Grants: DePuy Synthes/ISSG (D); Fellowship Support: AOSpine (F), NREF (F). ***SY:*** Nothing to disclose. ***VFL:*** Stock Ownership: Nemaris INC; Consulting: Globus Medical (D); Speaking and/or Teaching Arrangements: DePuy Spine (C); Grants: DePuy Spine (paid through ISSGF), Medtronic (paid through ISSGF), Allosource (paid through ISSGF), SiBone (paid through ISSGF), NuVasive (paid through ISSGF), Globus Medical (paid through ISSGF). ***TP:*** Consulting: Globus Medical (Money Paid to You Money to), K2M (Money Paid to You Money to), NuVasive (Money Paid to You Money to), Medicrea (Money Paid to You Money to), Innovasis (Money Paid to You Money to). ***PGP:*** Allosource: Personal Fees. Cervical Scoliosis Research Society: Personal Fees (Research Support), Globus Medical: Personal Fees (Paid Presenter or Speaker), Medicrea: Personal Fees (Paid Consultant), Spine-Wave: Personal Fees (Paid Consultant), Zimmer: Personal Fees (Paid presenter or speaker). ***FJS:*** Royalties: MSD (E); Stock Ownership: Nemaris INC (past) (Money Paid to You); Globus Medical (D), MSD (C), Zimmer Biomet (D); Speaking and/or Teaching Arrangements: Zimmer Biomet (B), K2M (B). ***Leah Y. Carreon:*** Consulting: AO Spine (B); Trips/Travel: Center for Spine Surgery and Research of the University of Southern Denmark (B), University of Louisville Institutional Review Board (B); Research Support (Investigator Salary, Staff/Materials): Scoliosis Research Society Research (B), OrthoBpedic Educational Research Fund (B), AO Spine, Scoliosis Research Society, Norton Healthcare (B).

*Corresponding author. Yoji Ogura, MD, Norton Leatherman Spine Center, 210 East Gray Street, Suite 900, Louisville, KY 40202, USA. Tel.: (502) 584-7525; fax: (502) 589-0849

E-mail address: yojitotti1223@gmail.com (Y. Ogura).

https://doi.org/10.1016/j.spinee.2020.03.018
1529-9430/

Abstract

BACKGROUND CONTEXT: Considerable debate exists regarding the optimal surgical approach for adult spinal deformity (ASD). It remains unclear which approach, posterior-only or combined anterior-posterior (AP), is more cost-effective. Our goal is to determine the 2-year cost per quality-adjusted life year (QALY) for each approach.

PURPOSE: To compare the 2-year cost-effectiveness of surgical treatment for ASD between the posterior-only approach and combined AP approach.

STUDY DESIGN: Retrospective economic analysis of a prospective, multicenter database

PATIENT SAMPLE: From a prospective, multicenter surgical database of ASD, patients undergoing five or more level fusions through a posterior-only or AP approach were identified and compared.

METHODS: QALYs gained were determined using baseline, 1-year, and 2-year postoperative Short Form 6D. Cost was calculated from actual, direct hospital costs including any subsequent readmission or revision. Cost-effectiveness was determined using cost/QALY gained.

RESULTS: The AP approach showed significantly higher index cost than the posterior-only approach ($84,329 vs. $64,281). This margin decreased at 2-year follow-up with total costs of $89,824 and $73,904, respectively. QALYs gained at 2 years were similar with 0.21 and 0.17 in the posterior-only and the AP approaches, respectively. The cost/QALY at 2 years after surgery was significantly higher in the AP approach ($525,080) than in the posterior-only approach ($351,086).

CONCLUSIONS: We assessed 2-year cost-effectiveness for the surgical treatment through posterior-only and AP approaches. The posterior-only approach is less expensive both for the index surgery and at 2-year follow-up. The QALY gained at 2-years was similar between the two approaches. Thus, posterior-only approach was more cost-effective than the AP approach under our study parameters. However, both approaches were not cost-effective at 2-year follow-up.

Keywords: Adult spinal deformity; Cost-effectiveness; Posterior-only approach; Combined anteroposterior approach; QALY; Complications

Introduction

Adult spinal deformity (ASD) is becoming an increasingly common disorder due to the growing elderly population [1]. A recent prospective study showed that surgical treatment is superior to nonsurgical treatment in symptomatic ASD with regards to improvement in health-related quality of life [2].

Posterior fusion surgery (PSF) has been a mainstay of the surgical treatment for ASD. A posterior-only approach is typically utilized to avoid staging a second trip to the operating room but can increase surgical time, intraoperative blood loss, proximal junctional failure, or pseudarthrosis [3].

On the other hand, some surgeons advocate combined anteroposterior (AP) approach to minimize these complications, especially pseudarthrosis in the setting of circumferential fusion [4,5]. Advantages with the anterior approach include less intraoperative bleeding and better restoration of lumbar lordosis using a large, lordotic interbody cage. However, staged combined AP procedures may increase the risk of infection or other medical complications [6,7].

Although effective, surgical treatment of ASD is expensive since it often requires blood transfusion, prolonged hospital stays, and complex procedures such as osteotomies, long segment spinal fusions or circumferential approach as well as relatively high reoperation rate up to 20% within 5 years [8−11]. No cost-effective analysis comparing posterior only to the AP approach has been performed. The purpose of this study was to perform a cost-effectiveness analysis comparing posterior only to the AP approach for ASD with a 2-year time horizon from the hospital perspective.

Methods

Subjects

From a prospective, multicenter ASD database, patients undergoing 5 or more level fusions with posterior-only or combined AP approach between 2008 and 2013 were identified. Patients were included if they were diagnosed with ASD, and complete 2-year follow-up health-related quality of life and direct cost data were available. ASD was defined as a coronal Cobb angle ≥20°, sagittal vertical axis ≥5 cm, pelvic tilt (PT) ≥25°, and thoracic kyphosis ≥60°. Patients with deformity secondary to neuromuscular disorders, connective tissue or autoimmune diseases, infection, malignancy, or trauma were excluded. Of 196 surgical ASD patients eligible for 2-year follow-up, 163 (83%) had complete preoperative and 2-year SF-6D data. Of these, 117 had complete cost data, and index and 2-year QALY data. Seventy-two patients underwent a posterior-only approach (PSF group) and 45 underwent a combined AP approach (AP group).

Cost-effectiveness analysis

Quality-adjusted life year (QALYs) gained were determined using preoperative, 1-year, and 2-year postoperative Short Form 6D (SF-6D). In brief, SF-6D was developed to evaluate economic value based on SF-36 [12]. Brazier et al. used the standard gamble valuation technique to obtain utility values on 249 of the possible health states of 836 respondents, and created an algorithm to generate a continuous index for health scored from 0 (dead) to 1 (perfect health) [12]. This SF-6D index was used in the assessment of the QALYs. Cost was calculated from actual, direct hospital costs and included any subsequent treatment of complications, readmission, revision, emergency room, or outpatient visits. Cost-effectiveness was determined by total cost per QALY. TreeAge Pro software was used to perform the cost-effectiveness analysis. A decision tree model was used to take into account the different incidence of revision surgeries between both groups.

Statistical analysis

Difference between groups were analyzed using Fisher exact probability test or Mann-Whitney *U* test depending on the variable type. All statistical analyses were performed using SPSS Statistics 25 (IBM Corp., Armonk, NY). A statistical significance was defined as p value <.05.

Results

Patient demographics are shown in Table 1. The PSF group had slightly lower score in baseline SF-6D, however, there was no difference in age, gender, BMI, ASA grade, or Charlson comorbidity index between the groups.

Surgery and hospital stay

In the PSF group, more osteotomies were performed compared with the AP group, and EBL was significantly greater. However, there was no difference in surgical time, levels fused, bone morphogenetic protein (BMP) use, and length of stay. All the patients underwent interbody fusion in the AP group whereas only 29% of the patients in the PSF group had an interbody fusion (Table 2).

Table 1
Background characteristics of the patients in each approach

Parameter	P group (n=72)	AP group (n=45)	p Value
Age (years)	58.7 ± 14.9	58.6 ± 7.7	.993
Gender (female %)	85	86	.772
BMI	28.2 ± 6.6	27.4 ± 5.1	.489
ASA grade	2.5 ± 0.6	2.4 ± 0.5	.380
CCI	2.0 ± 1.7	1.8 ± 1.8	.591
Baseline SF-6D	0.53 ± 0.11	0.59 ± 0.12	**.006**

Mean ± Standard Deviation.
PSF: posterior-only approach, AP: combined anterior-posterior approach.
ASA: American Society of Anesthesiologists; BMI: body mass index; CCI: Charlson comorbidity index; SF-6D: short form 6D.
Bold letters represent p<.05.

Table 2
Surgical and hospital stay characteristics of the patients in each approach

Parameters	PSF group (n=72)	AP group (n=45)	p Value
Surgical time (minutes)	404 ± 114	386 ± 150	.462
EBL (g)	1,643 ± 1,678	945 ± 895	**.015**
Levels fused	12.4 ± 3.9	12.2 ± 3.8	.789
Interbody fusion (%)	29	100	**<.001**
3COs (%)	29	13	**.048**
PSO (%)	25	8	**.011**
VCR (%)	4	4	.533
BMP use (%)	63	73	.227
Length of stay (days)	8.2 ± 6.0	7.4 ± 4.3	.437

Mean ± Standard Deviation.
PSF: posterior-only approach, AP: combined anterior-posterior approach.
BMP: Bone Morphogenetic Protein; EBL: Estimated Blood Loss; 3COs: three-column osteotomies; PSO: pedicle subtraction osteotomy; VCR: vertebral column resection.
Bold letters represent p<.05.

Revision surgery

There was no difference in the rate of revision surgery (Table 3) between the two groups. Nineteen patients (26%) underwent revision surgery in the PSF group whereas nine patients (20%) had a revision in the AP group (p=.508). In the PSF group, 15 patients had one revision surgery, two patients had two revisions, and two patients had three revisions after the index surgery within 2 years. In the AP group, 6 patients had one revision surgery, one patient had two revisions, and two patients had three revisions after the

Table 3
2-year revision surgery data in each approach

	PSF group (n=72)	AP group (n=45)	p Value
Patients undergoing revision (%)	19 (26%)	9 (20%)	.508
Number of revisions			
1	15	6	
2	2	1	
3	2	2	
Cause of revision			
Adjacent degeneration	1	1	1.000
Implant prominence/malposition	1	1	1.000
Infection	1	3	.158
DJK	1	0	1.000
PJK	8	4	.765
Malalignment	3	1	1.000
Neurological deficit	0	2	.146
Pseudarthrosis	10	2	.126

PSF: posterior-only approach, AP: combined anterior-posterior approach.
DJK: distal junctional kyphosis, PJK: proximal junctional kyphosis.

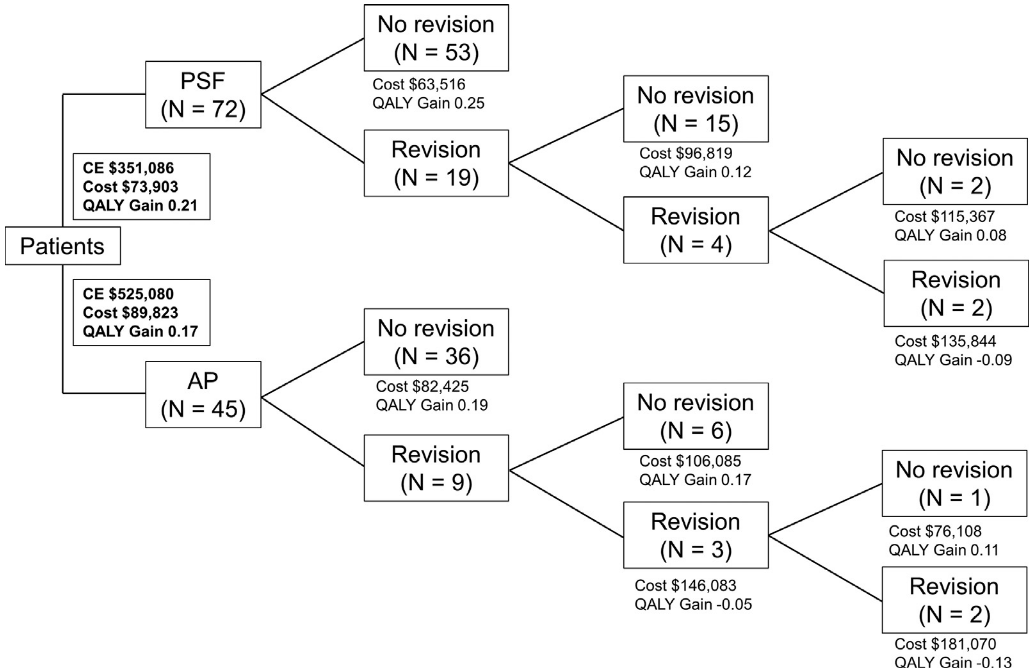

Figure. Decision tree for cost-effectiveness of posterior-only approach and anteroposterior combined approach. The cost-effectiveness (CE) and the incidence of revision in each stage. The posterior-only approach (PSF) is more cost-effective than combined anteroposterior approach (AP) at 2-year after surgery.

index surgery within 2 years (Figure). Infection was more common in the AP group and pseudarthrosis was more common in the PSF group, however, this difference was not statistically significant.

Cost-effectiveness

The cost/QALY at 2 years after surgery was significantly higher in the AP approach than in the posterior-only approach. Thus, the posterior-only approach was the dominant procedure and more cost-effective. Comparison of cost and QALY was shown in Table 4. QALY gained was 0.21 and 0.17 in the posterior-only and AP approach, respectively. The AP approach showed significantly higher cost than the posterior-only approach in the index surgery ($p<.001$) and the 2-year cumulative cost ($p=.011$). The margin at the index surgery decreased at 2-year follow-up. QALYs gained was slightly higher in the posterior-only approach although the difference was not statistically significant ($p=.317$).

Table 4
Comparison of cost and QALY between the two approaches

	PSF group (n=72)	AP group (n=45)	p Value
Cost			
Index	$64,281 ± 21,473	$84,329 ± 25,606	**<.001**
2-year total	$73,904 ± 33,394	$89,824 ± 31,594	**.011**
QALY			
2-year postoperative	1.27 ± 0.24	1.35 ± 0.26	.109
2-year improvement	0.21 ± 0.22	0.17 ± 0.20	.317
Cost effectiveness	$351,086	$525,080	**<.001**

Mean ± Standard Deviation.
PSF: posterior-only approach, AP: combined anterior-posterior approach.
QALY: quality-adjusted life years.
Bold letters represent $p<.05$.

Discussion

The last two decades have seen a rapid increase in the prevalence of ASD with a concomitant 4-fold increase in rates of surgical care for ASD [13]. As well, the cost has increased drastically with a 230% increase in CMS charges per inpatient stay for ASD surgery in the United States from 2000 to 2010 [14]. This rapid increase in prevalence and cost places a large target on ASD surgery for payors and policy makers. In efforts to provide value and to sustain our ability to perform these types of procedures, spine surgeons have a responsibility to understand the cost of care as well as clinical efficacy in the clinical setting. The goals of surgical treatment for ASD are to decompress the neural elements, restore coronal and sagittal alignment, and obtain a solid fusion while minimizing complications. A large variety of surgical approaches and techniques are available to achieve these goals, in which posterior-only and combined AP approaches have gained popularity. The optimal approach remains unclear in terms of clinical efficacy or cost-effectiveness.

Cost-effectiveness is another important factor since the treatment of ASD is costly regardless of the approach [15] and the number of surgeries for ASD is increasing. We assessed the cost-effectiveness of surgery through posterior-only and combined AP approaches. The index cost was significantly higher in the AP group ($84,329) than in the PSF group ($64,281). The higher initial cost in the AP group may be attributed to the staged procedure (51%). This trend was maintained at 2-year postoperatively although the 2-year total cost in the PSF group ($73,904) tended to catch up with costs in the AP group ($89,824). The PSF group had higher revision rate (26%) than the AP group (20%) although the difference was not statistically significant, which is the primary driver of the decreased cost gap between the groups at 2-year after surgery compared with the index cost.

Surgeons such as Suk and Lenke have advocated for posterior-only approach for ASD surgery and has since become increasingly common [16,17]. Advances in pedicle screw instrumentation and advances in posterior osteotomy techniques enable greater correction without the need for anterior releases [18]. Several studies compared the radiographic and clinical outcomes between posterior-only and combined approaches, and showed superior or equivalent clinical and radiographic outcomes and less perioperative complications in posterior-only approach [19−22]. However, a higher rate of pseudarthrosis of up to 17% has been reported in posterior-only approach [3]. Anterior approach provides a better environment for fusion by allowing for placement of bone graft with larger surface area in compression. This can minimize the risk of pseudarthrosis. In our cohort, pseudarthrosis was more prevalent in the PSF group (14%) compared with the AP group (4%). Some authors advocate the off-label use of rh-BMP to mitigate the risk of pseudarthrosis when treating with posterior-only approach [23]. The utilization of rh-BMP can increase the surgical cost in the posterior-only approach although there was no difference in rh-BMP use between the groups in our cohort. Anterior approach also allows effective sagittal correction and may eliminate the need for the three-column osteotomies (3COs) [4,5]. Our results mimic this finding with more 3COs performed with more EBL in the PSF group. Additionally, higher risk of infection and blood transfusion were reported in staged combined AP approach [24−26]. Similarly, in our cohort, infection was more common in the AP group.

There was no difference in the QALY gained at 2-year postoperatively with 0.21 in the PSF group and 0.17 in the AP group. The QALY gain of this study was consistent with previous ASD studies [27,28]. Fischer et al. examined the cost of ASD surgery, and estimated 2-year cost/QALY as $243,762 [27]. Similarly, Yagi et al. estimated 2-year cost/QALY as $511,840 in the United States and $225,668 in Japan [28]. These variations may be due to heterogeneous nature of ASD; ASD includes a variety of pathologies such as adult idiopathic scoliosis, de novo scoliosis and kyphosis. Patients with ASD consist of various age groups and have various comorbidities. In addition, the resource utilization, such as rh-BMP, other graft material, blood products and implant type, is at the discretion of surgeons. These multiple factors may contribute to the wide range of cost/QALY values reported.

Both groups had much higher cost/QALY than $100,000 per QALY which is the generally accepted cost-effectiveness threshold presented by the World Health Organization [29] although the cost-effectiveness, calculated with 2-year cost/QALY, was significantly higher in the AP group than the PSF group. Under the current study's time horizon (2-years) neither approach is considered cost-effective. The previous studies have shown that surgeries with a high index surgical costs do not yield cost-effectiveness in the short-term [30,31]. Glassman et al. examined the cost-effectiveness of single-level instrumented posterolateral lumbar fusion during a 5-year period [31]. The mean SF-6D health utility value increased gradually with a cumulative 0.69 QALY improvement during the 5-year interval, resulting in a gradual decrease in cost/QALY throughout the period. Similarly, Tosteson et al. examined the cost of lumbar fusion surgery for degenerative spondylolisthesis, and showed that fusion surgery was not cost-effective at 2-year but became cost-effective at 4-year after surgery [30]. The studies suggest that cost-effectiveness is largely influenced by the durability of the treatment. Bridwell et al. showed the surgery of ASD was relatively durable. They compared the clinical and radiographic outcomes between at the 2-year and 3- to 5-year points, which demonstrated that there was no deterioration in clinical and radiographic outcomes [32]. These findings imply that the two approaches could achieve cost-effectiveness with a longer follow-up period. Similarly, it may be possible for AP approach to become more cost-effective with a longer follow-up period as the conclusion will depend upon the ultimate revision or nonunion rate. Thus, analysis at 5-year or more after surgery is necessary to conclude.

There are limitations in this study. First, ASD includes heterogeneous pathologies such as idiopathic scoliosis, de novo scoliosis and kyphosis. The approach or techniques used may be different depending on the pathology. Second, this is a multicenter study and resource utilization is different depending on the surgeon/center. A recent multicenter study showed significant heterogeneity in resource use between medical centers [33]. The cost of instrumentation and biologics also varies largely based on vendor contracts and the granularity of this cannot be disclosed per the agreements. Pahlavan et al. investigated implant costs from six manufacturers at 45 medical centers. They found wide variation in costs of spinal implants between centers [34]. Finally, we discussed above the short time horizon of 2-years. Long-term revision rate will be critical for a realistic analysis.

It should also be highlighted that we utilized direct, actual cost for our cost metric. This provides a hospital perspective in terms of cost-effectiveness. We have previously published that using actual cost versus the typical cost-effectiveness metric of Medicare Allowable rates increases the overall cost side of the equation [35]. This is another potential cause for the high cost/QALY values. Using MA rates provides a societal perspective but does not account for the wide variability in implant density, implant selection, or biologic utilization.

In conclusion, we assessed 2-year direct cost and cost-effectiveness. The QALY gained at 2-years is similar between patients undergoing either posterior-only or combined AP approaches. Posterior-only approach is less expensive at index surgery, but this margin decreases at 2-year follow-up. Both approaches were not cost-effective at 2-year follow-up. Since the durability of treatment has an impact on cost-effectiveness, further study with longer-follow-up is necessary.

Conflicts of Interest

Authors declare that they have no conflict of interest.

Acknowledgment

This study was supported by ISSG foundation.

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