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EDITORIAL (BY INVITATION)

Adult spine deformity surgery—what do we miss?

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Despite the extraordinary advances in the last decades, adult spinal deformity (ASD) remains to this day one of the most formidable challenges presenting to spine surgeons. We have managed to improve by orders of magnitude our understanding of the biomechanical and pathophysiological principles on the basis of the disease, our diagnostic tools, the knowledge of the personal and socio-economic burden, and, more decisively, the surgical armamentarium available [8]. Though it is clear that we have come a long way since the Harrington rod, it is also undeniable that we often ended up less impressed by the results of surgery or overwhelmed by the complications it entails for a particularly frail patient group. In that sense, following the enthusiasm brought in by minimally invasive surgery (MIS) and techniques to the treatment of other spinal pathologies, the next obvious step was to try and adapt them to the treatment of degenerative adult deformity. The appeal was obvious: to minimize the aggressiveness of surgery and therefore costs/complications, while at least maintaining the same efficacy. This has been extensively studied, including comparative studies on the advantages and pitfalls of MIS vs open surgery [9], and MIS techniques have been progressively integrated in the rationale of surgical treatment [5]. However, very few studies have been published with follow-up greater than 2 years [1, 2], so long-term outcomes have been severely lacking.

This is the subject the article published in this issue of *Acta Neurochirurgica* by Michael Wang et al., as part of the MIS-ISSG (International Spine Study Group), tries to address. It retrospectively reviews the data of a multi-center (8 institutions) adult spinal deformity surgery database and evaluates demographics, clinical, radiological, and surgical parameters. It picks up on previously reported 2-year outcomes by the same group, this time with a minimal follow-up time of 4 years. Surgery offered was either circumferential MIS (cMIS) or hybrid, choosing between MIS anterolateral approach or a posterior open approach (HYB).

Before we comment on the results, it is important to note several limitations of the study, some acknowledged by the authors. Being retrospective in nature, it may be subject to under-reporting of complications; being non-randomized, the choice of procedure (cMIS, HYB, or traditional open) is essentially left at the discretion of the surgeon; the fact that is non-controlled limits its value when comparing with traditional open procedures; the percentage of patients that did not meet the inclusion criteria or were lost to follow-up is high at 54%. This needs to be taken into consideration while interpreting the results, because a total of 53 patients recruited from 8 institutions in a non-randomized/surgeon preference type of study introduce a significant amount of bias and significantly hinder the statistical power when trying to correct it.

Having said so, what the patient reported outcome measures (PROM) show is improvement in VAS back (6.9 to 4.8) and leg pain (6 to 2.78) and improvement in ODI scores (49.9 to 33.9), with the HYB group presenting with significant worse pre-op ODI scores; minimal clinically important difference (MCID) was measured by oswestry disability index (ODI) and peaked at 2 years with 61% reaching MCID thereafter falling to 45% at 4 years, with an overall loss of 24% at 4 years. The radiographic results showed PI-PL mismatch correction from 16.9 to 10.8°; Cobb angle correction of 37.9 to 18.3°; and sagittal vertical axis (SVA) correction from 40.7 to 35.2, with the HYB group having significantly worse preoperative SVA (57.7 vs 29). Complications were present in 56% of patients; reintervention rate was 39.6%, 20.8% due to proximal junctional kyphosis (PJK), and 11.3% and 18.9% due to infectious and neurological problems, respectively (this last one achieving a statistically significant difference from the HYB group vs cMIS—36.4% vs 6.5%).

What emerges from this data is that even though the two groups could be paired for the sake of empowering statistical analysis, they are in essence different in nature. Compared

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with the cMIS group, the HYB surgery group has worse preoperative imaging (SVA, PI-LL mismatch, Cobb angle), therefore requiring heftier corrections in order to obtain similar radiographic and clinical results. It comes as no surprise that this group needed more levels to be instrumented (9 vs 4.8), more OR time (763 vs 463 min), more extensive blood losses (1932 vs 392 cc), and registered more complications (68.2 vs 48.4%, with neurological complications reaching statistical significance). It would therefore be of great importance to clarify what the open surgery stage means in this group: is it facet resection or is it three-column osteotomies, one level or multiple levels? These are surgeries on different ends of the "least invasive possible" vs "maximally invasive available" spectrum of open surgery, with expectable impact on complication rates, and this is not taken into account in the analysis.

Not addressed as well is the effect of the learning curve and technical evolution on the results. Keeping in mind these are tertiary care and academic centers with great volume and expertise, it would be interesting to know if the clinical, radiographic, and surgical metrics improved with time and technical advances made available during the study period, as it has been shown in other studies [1, 10].

The authors discuss the value of the procedure at some length. Previous studies have suggested that ASD surgery is cost-effective after a 10-year period when compared with non-surgical treatment [4]. Although it is also true, as the authors point out, the effect of surgery goes well beyond the primary endpoints and might have a big long-term impact on mortality and other causes of morbidity [3]; the fact that the pain relief and disability improvements seem to wane with time does not bode well for the long-term value of the surgery (on a strict cost-effectiveness standpoint).

Having come to this point, we may ask ourselves: is there an elephant in the room? Why do results worsen with time? While it is true that a study that evaluates MCID based on ODI (a multidimensional and non-specific questionnaire by definition) is subject to interference from other medical or clinical conditions that may arise with time, the same argument does not hold as consistently when it comes to back and leg pain. Although the authors do not specifically mention it, we infer that postoperative radiographic parameters were stable during the follow-up period and there was no significant loss of deformity correction that might be held accountable for the worsening clinical outcomes. The authors do state that specific spinal structural reasons may contribute to loss of benefit, namely, adjacent level disease, non-union, instrumentation failure, and PJK (which occurred in 21% of all patients in the overall study group). It has in fact been shown, in studies that kept track of adult deformity surgical patients for 2 years and longer, that a more expressive residual deformity (evaluated by SVA) and the presence of major complications and revision surgery have a significant effect on outcomes [2, 7]. Although the senior author and the MIS-ISSG group have just published an interesting article addressing the patients that did not reach MCID [11], it also would have been interesting to know if the subset of patients in the current study that did reach MCID but fared progressively worse at 4 years postoperatively somehow correlated with insufficient deformity correction or complications sustained. Of note is that the overall results on radiological deformity correction and clinical outcomes fall in line with previous studies, although overall complication rates of 56.6% (48.4% for cMIS and 68.2% for HYB) are comparatively on the upper end [6, 9]. It would have been interesting to know with more detail the timeframe in which these complications occurred, as this could help clarify if this could be attributable to a longer follow-up period in which later stage complications (adjacent level disease, non-union, instrumentation failure, PJK) increasingly occur, as previously reported [2].

Regardless of all the issues we just raised for the sake of this important discussion, we would like to give a heartfelt commendation to the authors on the work they present. This is one of the first studies evaluating outcomes of MIS adult deformity surgery with follow-up longer than 2 years. The results show that radiographic and clinically significant improvement can be reached with MIS surgery, although it must be emphatically stated at the cost of a high complication rate. Similarly, the extent of improvement seems to lessen over time, for reasons not entirely possible to clarify with the data available. Going forward, it would be important that future studies increase the granularity of the data and results and might try to focus on the risk/benefit and subgroup analysis—as usual, the devil is in the details. The authors state that these are intermediate results, so we really look forward to seeing if the results of an even longer follow-up period might shed some more light on this fascinating and ever evolving surgical challenge.

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