临床论著

颈椎前路 Hybrid 手术不同组合方式治疗连续三节段颈椎病的疗效对比

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【摘要】目的:比较不同组合方式颈椎前路 Hybrid 手术 [颈前路椎间盘切除减压融合术 (anterior cervical discectomy and fusion,ACDF)+人工颈椎间盘置换术(cervical disc arthroplasty,CDA)]治疗连续三节段颈椎病的临床疗效。**方法**:回顾性分析 2012 年 6 月~2018 年 12 月因连续三节段颈椎病于我科行手术治疗的病例,根据手术方式的不同分为 FFF 组(连续三节段 ACDF 患者)、1A2F 组(单节段 CDA+双节段 ACDF 患者)和 2A1F 组(双节段 CDA+单节段 ACDF 患者)。根据纳入排除标准,共 98 例患者纳入研究,其中 FFF 组 22 例,年龄 58.95±9.28 岁,随访时间为 29.23±14.79 个月;1A2F 组 47 例,年龄 51.70±8.23 岁,随访时间为 36.09±16.72 个月;2A1F 组 29 例,年龄 48.72±7.76 岁,随访时间为 36.58±14.81 个月。对比分析三组患者术前与术后 3d、3 个月、6 个月、12 个月及末次随访时颈部及上肢疼痛视觉模拟评分 (visual analog scale,VAS)、日本骨科协会(Japanese Orthopedic Association,JOA)脊髓功能评分及颈椎残障功能指数(neck disability index,NDI)评分。同时于术前与术后 3d、3 个月、6 个月、12 个月及末次随访时在颈椎侧位及过伸过屈位 X 线片上测量颈椎 C2–C7 曲度、手术节段曲度、颈椎 C2–C7 活动度、手术节段活动度、上位邻近节段活动度,末次随访时结合颈椎 CT 评估 ACDF 节段融合情况。**结果**:三组患者术后各时间点颈痛 VAS 评分、上肢痛 VAS 评分和 JOA 评分均较术前显著改善(P<0.05),三组之间无显著性差异(P>0.05)。术后 3 个月时 FFF 组 NDI 评分为 17.86±2.55 分,显著高于 1A2F 组的 15.13±3.76 分和 2A1F 组的 15.55±4.07 分 (P<0.05),余时间点三组之间无显著性差异 (P>0.05)。三组患者术后 3d 时颈椎 C2–C7 曲度和手术节段曲度均较术前显著改善(P<0.05)。末次随访时,FFF 组颈椎 C2–C7 曲度和手术节段曲度均较术前显著降低 (P<0.05),1A2F 组和 2A1F 组与术前相比无显著性差异(P>0.05),三组之间无显著性差异(P>0.05)。术后 6 个月、12 个月及末次随访时,FFF 组颈椎 C2–C7 活动度及手术节段活动度均显著低于 1A2F 组和 2A1F 组 (P<0.05)。术后 12 个月时,2A1F 组颈椎 C2–C7 活动度高于 1A2F 组(P<0.05)。术后 12 个月及末次随访时,2A1F 组手术节段活动度高于 1A2F 组(P<0.05)。末次随访时,FFF 组、1A2F 组和 2A1F 组上位邻近节段活动度分别为 11.97°±2.27°、9.80°±2.99°和 8.45°±2.26°, 三组之间及两两比较均有显著性差异 (P<0.05)。末次随访时 FFF 组、1A2F 组和 2A1F 组融合率分别为 81.82%(18/22)、91.49%(43/47)和 96.55%(28/29),差异无统计学意义(P>0.05)。**结论**:相较于单纯三节段 ACDF,颈椎前路 Hybrid 手术能够获得与其一致的临床疗效,但在早期颈椎功能康复、颈椎整体活动度及对邻近节段影响方面更具优势,且双节段 CDA+单节段 ACDF 组合方式比单节段 CDA+双节段 ACDF 更优。

【关键词】三节段颈椎病;Hybrid 手术;颈前路椎间盘切除减压融合术;组合方式;手术效果
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The clinical effects of cervical anterior Hybrid surgery for the treatment of contiguous 3–level cervical degenerative disc disease: a comparative study among different constructs/HUANG Kangkang, LIU Hao, DING Chen, et al//Chinese Journal of Spine and Spinal Cord, 2021, 31(9): 771–782

【Abstract】 Objectives: To explore the clinical effects of anterior cervical Hybrid surgery [anterior cervical discectomy and fusion(ACDF) + cervical disc arthroplasty(CDA)] for the treatment of contiguous 3–level cervi-

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cal degenerative disc disease among different constructs. **Methods:** Between June 2012 and December 2018, data of patients with contiguous three levels cervical degenerative disc disease who underwent 3-level ACDF or 3-level anterior cervical Hybrid surgery in our hospital were reviewed. The patients were divided into FFF group(3-level ACDF), 1A2F group (1-level CDA and 2-level ACDF), and 2A1F group(2-level CDA and 1-level ACDF). According to the inclusion and exclusion criteria, a total of 98 patients were included with 22 patients in FFF group, 47 patients in 1A2F group, and 29 patients in 2A1F group. The average age in FFF group, 1A2F group and 2A1F group was 58.95±9.28 years, 51.70±8.23 years and 48.72±7.76 years, respectively. The average follow-up time in FFF group, 1A2F group and 2A1F group was 29.23±14.79 months, 36.09±16.72 months and 36.58±14.81 months, respectively. The differences of visual analog scale(VAS) scores of the neck and arm, the Japanese Orthopedic Association(JOA) scores and neck disability index(NDI) among groups were compared preoperatively and at 3 days, 3 months, 6 months, 12 months postoperatively and at the final follow-up. Cervical lordosis(CL), Cobb angle of surgical levels, range of motion(ROM) of the total cervical spine, ROM of surgical levels and ROM of the adjacent segments were measured via lateral X-rays in flexion-extension and neutral positions preoperatively and at 3 days, 3 months, 6 months, 12 months postoperatively and at the final follow-up. Fusion conditions were assessed according to flexion-extension X-rays and CT at the final follow-up. **Results:** After surgery, all patients in the three groups showed significant increase in JOA scores(P<0.05) and significant decrease in VAS scores of the neck and arm(P<0.05), yet there were no differences among the three groups(P>0.05). The NDI score in FFF group at 3 months postoperatively was 17.86±2.55, which was significantly higher than that of 1A2F and 2A1F groups(P<0.05), 15.13±3.76 and 15.55±4.07, respectively. The Cobb angles of the total cervical spine and the surgical levels were increased significantly at 3 days postoperatively compared with the value preoperatively in all three groups (P<0.05). However, at the final follow-up, the Cobb angles of the total cervical spine and the surgical levels were significantly lower than those preoperatively in FFF group (P<0.05). There were no significant differences of the Cobb angles of the total cervical spine and the surgical levels at the final follow-up among the three groups (P>0.05). The ROMs of the total cervical spine and the surgical levels in FFF group at 6, 12 months postoperatively and the final follow-up were significantly lower than those in 1A2F and 2A1F groups(P<0.05). The ROM of the total cervical spine in 2A1F group was significantly higher than those in 1A2F group at 12 months postoperatively(P<0.05). The ROMs of the surgical levels in 2A1F group were significantly higher than those in 1A2F group at 12 months postoperatively and the final follow-up(P<0.05). At the final follow-up, the ROMs of the superior adjacent segment of FFF group, 1A2F group and 2A1F group were 11.97°±2.27°, 9.80°±2.99° and 8.45°±2.26°, respectively, of which significant differences were observed among the three groups and between each two groups(P<0.05). At the final follow-up, fusion rate was 81.82%(18/22) in FFF group, 91.49%(43/47) in 1A2F group and 96.55%(28/29) in 2A1F group, without significant difference among groups (P>0.05). **Conclusions:** Compared with 3-level ACDF, the clinical outcomes of 3-level Hybrid surgery were satisfied. In addition, the Hybrid groups had a higher ROMs of the cervical spine and lower influence on the superior adjacent segment, especially in the group of 2-level CDA and 1-level ACDF construct.

【Key words】 3-level cervical degenerative disc disease; Hybrid surgery; Anterior cervical discectomy and fusion; Constructs; Operative outcome

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颈前路椎间盘切除减压融合术(anterior cervical discectomy and fusion,ACDF)是治疗颈椎病的经典术式之一。有研究表明 ACDF 在治疗连续三节段颈椎病中安全有效[1,2],但存在颈椎活动度丢失、低融合率、高吞咽困难发生率、邻近节段退变加速、高内置物相关并发症发生率等问题[3,4]。人工颈椎间盘置换术(cervical disc arthroplasty,CDA)因其具有保留节段活动度、降低邻近节段压力等优势而被认为是一种可供选择的有效术式,已应用于单节段及双节段颈椎病的治疗[5-7]。但因生物力学的复杂性,其在连续三节段颈椎病中的应用极为有限。虽有学者进行临床探索,认为其治

疗三节段颈椎病亦是有效[8]。但因缺乏相关基础研究及大样本量报道,且存在手术适应证狭窄、手术难度大、费用高昂、颈椎生物力学环境改变大等问题,目前尚未被广泛认可。CDA 联合 ACDF 的混搭手术,即颈椎前路 Hybrid 手术,充分考虑了多节段颈椎病中不同病变节段退变程度不同的特点,被认为是一种折中的可行方案。不少学者报道了 Hybrid 手术在连续三节段颈椎病的应用,认为其结合了 ACDF 及 CDA 的优势,临床疗效确切,在保留颈椎活动度方面优于连续三节段 ACDF[9,10]。但目前关于 Hybrid 手术不同组合方式治疗连续三节段颈椎病的研究极少。本研究着重于通过不同组合方式的对比,观察 Hybrid 手术治疗连续三节段颈椎病的临床疗效。

1 资料与方法

1.1 病例选择

本研究采用回顾性分析的方法,纳入 2012 年 6 月~2018 年 12 月因连续三节段颈椎病于我科行手术治疗的病例。纳入标准:①病变节段为 C3~C7 之间的连续三节段颈椎病患者;②手术方式包括连续三节段 ACDF 及 Hybrid 手术;③人工椎间盘假体为 Prestige-LP(Medtronic Sofamor Danek, Memphis,TN,USA)、椎间融合器假体为 Zero-P (Synthes,Oberdorf,Switzerland);④随访资料完整且随访时间不少于 12 个月;⑤所有手术均为同一主刀医生完成。排除标准:①存在颈椎发育畸形者;②合并颈椎外伤、肿瘤、感染性病变者;③随访资料不齐;④不同意参加研究者。本研究经四川大学华西医院生物医学伦理委员会批准[2019 年审(567)号],所有患者均签署知情同意书。

1.2 分组方法

根据 CDA 和 ACDF 数量的不同,将符合纳入排除标准的患者分为三组:FFF 组,行连续三节段 ACDF 患者;1A2F 组,行单节段 CDA+双节段 ACDF 患者;2A1F 组,行双节段 CDA+单节段 ACDF 患者。

1.3 一般资料

2012 年 6 月~2018 年 12 月共收治 113 例连续三节段颈椎病手术病例(所用假体为 Prestige-LP 及 Zero-P),其中 15 例因随访资料不完整予以剔除(FFF 组 3 例,1A2F 组 6 例,2A1F 组 6 例),失访率约 13.3%(FFF 组 12%,1A2F 组 11.3%,2A1F 组 17.1%)。最终共 98 例患者纳入本研究,FFF 组 22 例,其中男 11 例、女 11 例,年龄 58.95±9.28 岁(36~70 岁),随访时间为 29.23±14.79 个月(12~58 个月);1A2F 组 47 例,其中男 24 例、女 23 例,年龄 51.70±8.23 岁(33~60 岁),随访时间为 36.09±16.72 个月 (12~73 个月);2A1F 组 29 例,其中男 13 例、女 16 例,年龄 48.72±7.76 岁(30~61 岁),随访时间为 36.58±14.81 个月(12~71 个月)。

1.4 治疗方法

1.4.1 手术方式选择指征 病变节段行手术治疗的指征:①病变节段存在脊髓神经压迫,且引起相应临床症状、体征,影像表现与临床症状及体征定位一致;②患者临床症状经保守治疗至少 6 周仍未见缓解;③排除神经系统病变等其他疾病;④患者及家属知情同意。

病变节段行 CDA 的指征:①3°<矢状面椎间活动度<11°;②矢状面椎间位移<3mm;③椎间高度丢失<50%;④椎间隙前后缘无骨赘形成或骨赘小于椎体前后径的 1/8;⑤小关节无退变或轻度退变(参照颈椎小关节定量评分系统[11])。CDA 手术指征与文献报道[12]一致。

病变节段行 ACDF 的指征[12]:①手术节段失稳 (矢状面椎间位移≥3mm 或活动度≥11°);②活动度明显丢失(矢状面活动度≤3°);③椎间高度明显丢失(≥50%);④椎间隙前后缘骨赘形成且大于椎体前后径的 1/8;⑤小关节中重度退变(参照颈椎小关节定量评分系统[11])。

1.4.2 手术方法 患者全麻后取仰卧位,肢体与手术床长轴一致,颈部呈生理前凸中立位,头部垫圆枕固定,双肩及头部用胶带固定。定位并标记手术切口后行标准的右侧 Smith-Robinson 颈前入路显露手术区域。透视确定手术节段无误后,用尖刀和刮匙切除椎间盘,用磨钻、椎板咬骨钳等完成三个节段的充分减压。Hybrid 手术以先置换后融合的处理顺序,完成终板准备后,置换节段使用 Prestige-LP 专用试模透视下确定合适高度和前后径的假体,钻孔及开槽后彻底冲洗椎间隙,置入适合规格的 Prestige-LP 人工椎间盘假体。融合节段使用 Zero-P 专用试模确定合适大小的假体,透视确认后置入填充人工骨的 Zero-P 零切迹椎间融合固定器,再次确认位置后置入 4 枚螺钉。透视确认假体位置和颈椎曲度后,冲洗伤口、彻底止血

并放置血浆引流管,逐层缝合切口。三节段 ACDF 手术按上述方法置入 3 枚 Zero-P 零切迹椎间融合固定器。

术后 24h 内常规应用抗生素预防感染。拔除引流管后即可在颈托保护下下床活动。Hybrid 手术患者术后 3 周内适当进行颈部功能锻炼（进行前屈、后伸、左右侧偏、左右旋转 6 个动作,每天 3 次，每次 10~15 组),3 周后进行严格颈部制动至术后 3 个月。三节段 ACDF 患者术后即进行严格颈部制动至术后 3 个月。

1.5 观察指标

临床疗效的观察指标包括疼痛视觉模拟评分(visual analog scale,VAS)、日本骨科协会(Japanese Orthopedic Association,JOA)脊髓功能评分（满分 17 分）及颈椎残障功能指数(neck disability index,NDI)评分(以分值为统计数据,满分 50 分)。

影像学结果的观察指标包括颈椎 C2-C7 曲度、手术节段曲度、颈椎 C2-C7 活动度、手术节段活动度、上位邻近节段活动度、ACDF 节段融合情况等。曲度及活动度的测量采用经典的 Cobb 角测量方法[13],于颈椎侧位及过伸过屈位 X 线片上测得(图 1)。颈椎曲度为 C2 下终板与 C7 下终板切线之间的夹角；手术节段曲度为手术节段上位椎体上终板与下位椎体下终板切线之间的夹角；颈椎椎间隙节段 Cobb 角为椎间隙上下终板切线之间的夹角。颈椎 C2-C7 活动度为过伸位所测 C2-C7 Cobb 角与过屈位所测 C2-C7 Cobb 角之和(角度同向为差值);手术节段活动度为过伸位所测手术节段 Cobb 角与过屈位所测手术节段 Cobb 角之和(角度同向为差值);椎间活动度为过伸位所测椎间隙节段 Cobb 角与过屈位所测椎间隙节段 Cobb 角之和(角度同向为差值)。植骨融合的判定标准[14]:①颈椎过伸过屈位 X 线片测得椎间活动度小于 2°；②颈椎 CT 骨三维重建上观察到椎间隙有连续性骨小梁形成。因部分患者下位邻近节段存在遮挡,无法进行活动度测量,故未纳入下位邻近节段活动度数据。

VAS 评分、JOA 评分、颈椎 C2-C7 曲度和手术节段曲度的观察时间点包括术前与术后 3d、3 个月、6 个月、12 个月及末次随访。NDI 评分、颈椎 C2-C7 活动度、手术节段活动度和上位邻近节段活动度的观察时间点包括术前与术后 3 个月、6 个月、12 个月及末次随访。ACDF 节段融合情况的观察时间点为末次随访时。

1.6 统计分析

采用 SPSS 19.0 统计软件进行分析，计量资料采用均数±标准差的方式表示。术后各时间点数据与术前的对比采用配对 t 检验进行分析,三组样本之间的比较采用方差分析的方法，两两之间的比较采用 SNK 法。计数资料采用卡方检验进行分析。P<0.05 为差异有统计学意义。

2 结果

FFF 组 9 例患者手术节段为 C3~C6,13 例为 C4~C7;1A2F 组 12 例患者手术节段为 C3~C6,35 例为 C4~C7;2A1F 组 9 例患者手术节段为 C3~C6,20 例为 C4~C7，三组患者手术节段分布无显著性差异(P>0.05)。FFF 组、1A2F 组和 2A1F 组手术时间分别为 155.00±23.25min、167.45±23.54min 和 178.62±24.45min,三组间两两比较均存在显著性差异(P<0.05)。FFF 组、1A2F 组和 2A1F 组术中

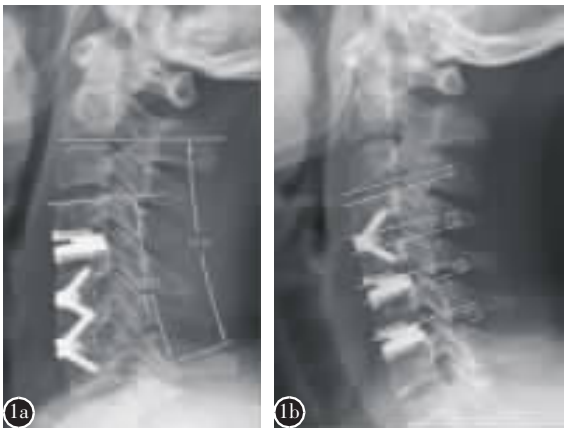

图 1 在颈椎侧位 X 线片上测量 **a** 颈椎 C2-C7 曲度:C2 下终板与 C7 下终板切线之间的夹角;手术节段曲度:手术节段上位椎体上终板与下位椎体下终板切线之间的夹角 **b** 颈椎间隙节段 Cobb 角：椎间隙上下终板切线之间的夹角

Figure 1 Measurements of cervical spine on lateral X-ray films **a** Cervical lordosis: the angle between tangent lines of C2 and C7 vertebral lower endplate; the angle of surgical levels: the angle between tangent lines of uppermost surgical vertebral upper endplate and lowest vertebral lower endplate **b** The Cobb angle of each level on lateral X-ray of the cervical spine (the angle between tangent lines of the intervertebral upper and lower endplates)

出血量分别为 66.82±24.95ml、69.36±28.70ml 和 80.69±21.70ml，三组间两两比较均无显著性差异（*P*>0.05）。

三组患者术前与术后各时间点的 VAS 评分、JOA 评分与 NDI 评分结果见表 1。三组患者术后颈痛 VAS 评分、上肢痛 VAS 评分、颈椎 JOA 评分和颈椎 NDI 评分均较术前明显改善，术后各时间点与术前比较差异均有统计学意义（*P*<0.05）。术后 3 个月时 FFF 组 NDI 评分显著高于 1A2F 组和 2A1F 组（*P*<0.05）。余各随访时间点三组之间比较和两两比较均无明显显著（*P*>0.05）。

三组患者术前与术后各时间点的 C2–C7 曲度、手术节段曲度、颈椎 C2–C7 活动度、手术节段活动度、上位邻近节段活动度见图 2。三组患者术后 3d 时颈椎 C2–C7 曲度和手术节段曲度均较术前显著改善（*P*<0.05）。末次随访时，FFF 组颈椎 C2–C7 曲度和手术节段曲度均较术前显著降低（*P*<0.05），1A2F 组和 2A1F 组与术前相比无显著性差异（*P*>0.05）。术后 6 个月时，FFF 组颈椎 C2–C7 曲度为 5.96°±4.91°，明显低于 1A2F 组的 9.50°±6.81°和 2A1F 组的 11.49°±8.15°，差异有统计学意义（*P*<0.05）。术后 3 个月、6 个月、12 个月及末次随访时 FFF 组颈椎 C2–C7 活动度显著低于 1A2F 组和 2A1F 组（*P*<0.05）。术后 12 个月时，1A2F 组和 2A1F 组颈椎 C2–C7 活动度分别为 29.20°±9.23°、34.38°±9.01°，两组比较差异有统计学意义（*P*<0.05）。术后 6 个月、12 个月及末次随访时 FFF 组手术节段活动度显著低于 1A2F 组和 2A1F 组（*P*<0.05）。1A2F 组与 2A1F 组相比，术后 12 个月时手术节段活动度（13.47°±7.28° vs 17.97°±5.88°，*P*<0.05）及末次随访时手术节段活动度（11.76°±6.92° vs 16.29°±5.87°，*P*<0.05）均有显著性差异。末次随访时，FFF 组、1A2F 组和 2A1F 组上位邻近节段活动度分别为 11.97°±2.27°、9.80°±2.99°和 8.45°±2.26°，三组之间比较及两两比较均有显著性差异（*P*<0.05）。

末次随访时 FFF 组、1A2F 组和 2A1F 组融合率分别为 81.82%（18/22）、91.49%（43/47）和 96.55%（28/29），差异无统计学意义（*P*>0.05）。术后 37 个月时 1A2F 组有 1 例患者出现邻椎病，予以二次手术，其余患者均无严重并发症。FFF 组、1A2F 组和 2A1F 组典型病例见图 3~5。

3 讨论

颈椎前路 Hybrid 手术自问世以来，学者们从临床疗效、生物力学等方面进行了诸多研究。Xiong 等 [15] 对 20 例双节段 Hybrid 手术进行了 6 年以上随访，与同期双节段 ACDF 相比，Hybrid 手术具有相似临床疗效，而 Hybrid 手术组颈椎整体活动度优于双节段 ACDF 组，且 Hybrid 手术组上位邻近节段活动度显著低于双节段 ACDF 组，证明 Hybrid 手术在减缓邻近节段退变方面优于 ACDF。Park 等[16]利用生物力学方法，在人新鲜颈椎标本上，将双节段 Hybrid 手术与双节段 ACDF、双节段 CDA 进行了对比分析，发现 Hybrid 手术在降低邻近节段椎间及小关节压力方面等同于双节段 CDA 且均优于双节段 ACDF。目前，双节段 Hybrid 手术已被认可为一种安全有效的手术方式。

颈椎前路 Hybrid 手术治疗连续三节段颈椎病的临床疗效亦被不少学者所报道。Shi 等 [17]对 36 例行连续三节段 Hybrid 手术的颈椎病患者进行了 2 年以上的随访，除 1 例因邻椎病而行二次手术外，其余患者均疗效满意，无手术相关并发症。关于三节段 Hybrid 手术的生物力学及有限元分析也提示其在保留手术节段活动度、降低邻近节段椎间及小关节压力方面优于三节段 ACDF[18,19]。一篇关于多节段 Hybrid 手术与 ACDF 对比的系统评价纳入了 4 篇双节段 Hybrid 手术和 4 篇三节段 Hybrid 手术，通过分析指出多节段 Hybrid 手术临床效果不亚于 ACDF，且能够一定程度地保留颈椎活动度[20]。但目前针对三节段颈椎前路 Hybrid 手术的组合方式进行临床报道极少。

本中心自 2006 年于国内外首次尝试颈椎前路 Hybrid 手术以来，多项研究均表明 Hybrid 手术是一种安全有效的手术方式[21~24]。本研究中我们根据三节段 Hybrid 手术中 CDA 与 ACDF 数量的不同分为 1A2F 组和 2A1F 组，并将两组临床疗效和影像结果与三节段 ACDF 进行对比分析。三组患者手术时间存在显著性差异，2A1F 组最高，1A2F 组次之，FFF 组最小，我们认为这是由于 CDA 比 ACDF 需要更长的手术时间。临床疗效方面，我们发现三组患者术后各随访时间点的颈痛和上肢痛 VAS 评分、JOA 评分、NDI 评分均较术前有明显改善，表明三种手术方式均能取得较好

表 1 3 组患者 VAS 评分、JOA 评分、NDI 评分比较

Table 1 The VAS, JOA and NDI scores of three groups

	FFF组 (*n*=22) FFF group	1A2F 组 (*n*=47) 1A2F group	2A1F 组 (*n*=29) 2A1F group	*P*值 *P* value			
				三组间 Among three groups	FFF vs 1A2F	FFF vs 2A1F	1A2F vs 2A1F
颈痛 VAS VAS score of neck pain							
术前 Pre-operative	5.36±1.40	4.83±1.37	4.72±1.33	0.216	0.134	0.101	0.744
术后 3d Po-3d	3.09±0.68	3.30±0.81	3.24±0.83	0.597	0.312	0.501	0.762
术后 3 个月 Po-3m	2.41±0.80	2.28±0.65	2.62±1.05	0.210	0.532	0.363	0.078
术后 6 个月 Po-6m	1.86±0.56	1.87±0.65	2.10±0.67	0.257	0.958	0.186	0.128
术后 12 个月 Po-12m	1.32±0.72	1.43±0.83	1.76±0.87	0.118	0.613	0.060	0.088
末次随访 Final follow-up	0.82±0.66	0.87±0.74	1.03±0.68	0.498	0.767	0.282	0.334
上肢痛 VAS VAS score of arm pain							
术前 Pre-operative	4.77±1.02	4.04±1.64	4.34±1.84	0.208	0.079	0.344	0.423
术后 3d Po-3d	2.27±0.88	2.13±1.30	2.21±1.21	0.888	0.638	0.845	0.778
术后 3 个月 Po-3m	1.91±0.81	1.79±0.91	1.90±0.82	0.804	0.585	0.959	0.592
术后 6 个月 Po-6m	1.23±0.75	1.23±0.98	1.62±0.94	0.170	0.977	0.135	0.080
术后 12 个月 Po-12m	1.00±0.69	1.02±0.87	1.34±0.86	0.203	0.921	0.145	0.102
末次随访 Final follow-up	0.50±0.60	0.85±1.12	0.83±0.66	0.297	0.136	0.203	0.913
JOA评分 JOA score							
术前 Pre-operative	9.73±0.77	10.15±1.41	10.07±1.07	0.390	0.176	0.315	0.778
术后 3d Po-3d	11.36±1.26	11.28±1.46	11.34±1.34	0.962	0.808	0.962	0.835
术后 3 个月 Po-3m	13.86±1.17	14.25±1.09	13.86±1.15	0.233	0.182	0.996	0.143
术后 6 个月 Po-6m	14.86±1.04	14.83±1.24	14.76±1.06	0.943	0.909	0.746	0.793
术后 12 个月 Po-12m	15.36±1.05	15.43±1.31	15.07±1.03	0.430	0.840	0.380	0.204
末次随访 Final follow-up	16.23±0.92	16.19±1.24	16.20±0.86	0.992	0.898	0.947	0.952
NDI评分 NDI score							
术前 Pre-operative	30.18±4.03	29.10±4.68	28.07±4.53	0.254	0.357	0.100	0.331
术后 3 个月 Po-3m	17.86±2.55	15.13±3.76	15.55±4.07	0.015	0.004	0.026	0.622
术后 6 个月 Po-6m	13.00±2.62	11.28±4.15	11.76±4.01	0.222	0.084	0.253	0.594
术后 12 个月 Po-12m	10.18±3.10	8.13±4.30	9.86±4.30	0.077	0.053	0.782	0.074
末次随访 Final follow-up	6.5±2.50	4.98±5.79	5.76±3.33	0.421	0.201	0.567	0.472

Note: Po, postoperative; 3d, 3 days; 3m, 3 months; 6m, 6 months; 12m, 12 months

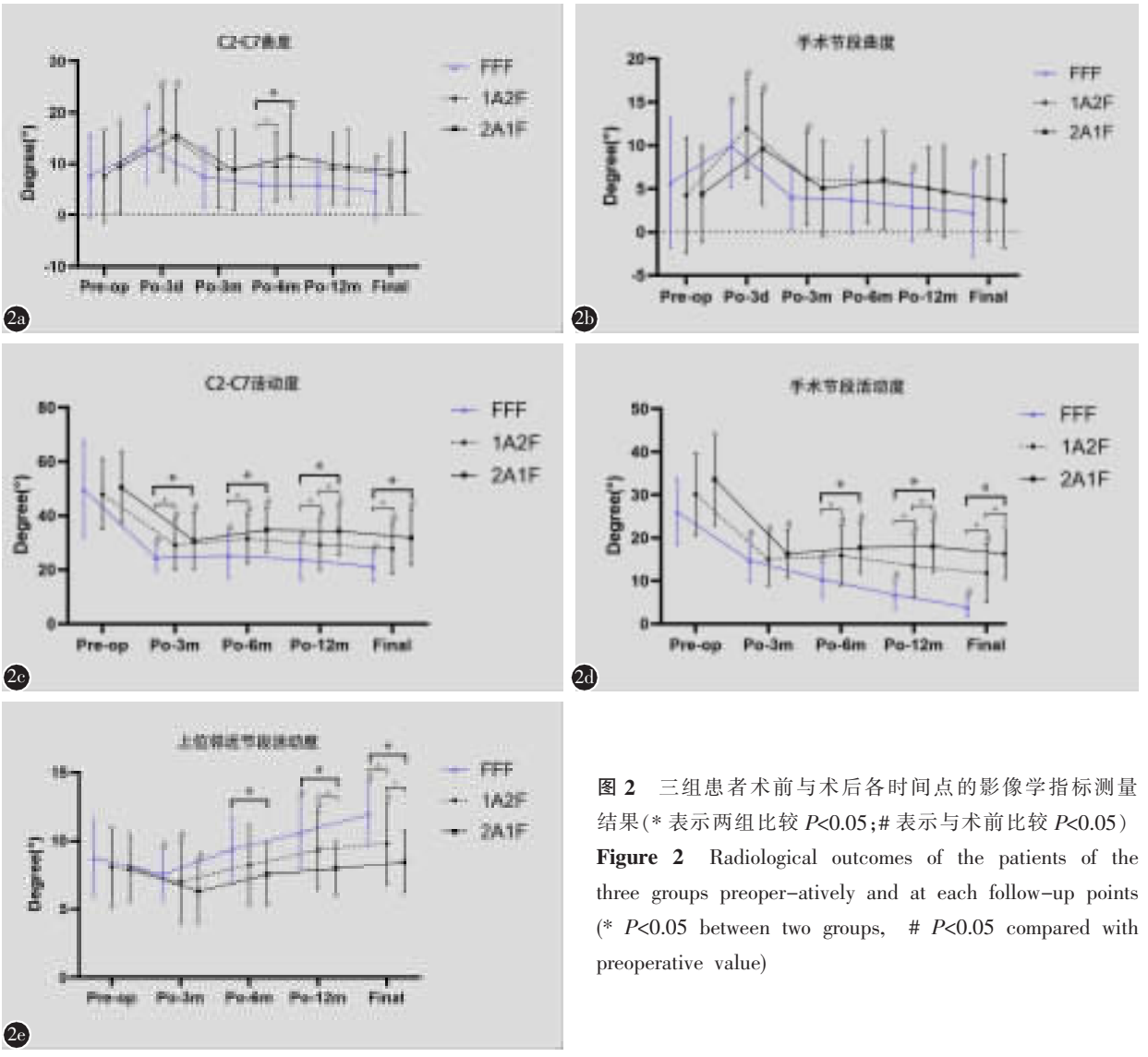

图 2 三组患者术前与术后各时间点的影像学指标测量结果(* 表示两组比较 $P<0.05$;# 表示与术前比较 $P<0.05$)

Figure 2 Radiological outcomes of the patients of the three groups preoper-atively and at each follow-up points (* $P<0.05$ between two groups, # $P<0.05$ compared with preoperative value)

的临床疗效。术后 3 个月时 FFF 组 NDI 评分高于 1A2F 组和 2A1F 组,表明 Hybrid 手术具有较好的早期康复效率。我们认为这种优势可能与保留颈椎活动度及早期功能锻炼有关,确切效果仍有待于大样本前瞻性研究进行验证。

与传统钢板相比,Zero-P 零切迹椎间融合器的优势在于降低术后吞咽苦难发生率[25]。但研究表明其在维持颈椎曲度方面不如传统钢板[26]。本研究中,三组患者术后 3d 时颈椎曲度均较术前显著改善,表明零切迹假体能够实现颈椎曲度的纠正与改善。但在随访期间,颈椎曲度与术前的差异逐渐缩小,可能是由于零切迹假体对曲度的维持能力有限。末次随访时,FFF 组颈椎曲度较术前显著降低,而 1A2F 组和 2A1F 组与术前相比无显著性差异,这可能是由于术前选择偏倚及 ACDF 和 CDA 手术操作不同造成的差异。

Kang 等[9]的研究表明,在术后 2 年时三节段 Hybrid 手术组颈椎 C2-C7 活动度由术前的 48.60°±12.1°降低至 45.90°±11.8°,而三节段 ACDF 组颈椎 C2-C7 活动度由术前的 47.20°±10.3°降低至 36.10°±8.90°,两者相比差异有统计学意义($P<0.05$)。Liao 等[18]采用颈椎新鲜标本生物力学研究的方法对比分析了 3DPD(上 CDA+中 ACDF+下 CDA)、3PDP(上 ACDF+中 CDA+下 ACDF)和 3P(三节段 ACDF)的生物力学特点,发现 3P 组颈椎整体活动度丢失明显,手术节段活动度丢失约 80%;3DPD 组颈椎整体活动度稍有增加($P>0.05$,最大增加约 7%),手术节段活动度稍有丢失($P>0.05$,最大丢失约 9%);3PDP 组颈椎整体活动度丢失明显($P<0.05$),手术节段活动度

图 3 FFF 组典型病例,69 岁女性患者 **a** 术前颈椎侧位 X 线片示 C2–C7 曲度为 19.79°,C3–C6 曲度为 13.12°,C4/5、C5/6 椎间隙后方骨赘形成,C5/6 椎间隙高度丢失 **b、c** 术前颈椎过伸过屈位 X 线片示 C2–C7 活动度为 31.44°,C3–C6 活动度为 22.78°,C2/3、C3/4、C4/5、C5/6 活动度分别为 5.28°、1.15°、8.03°、8.22° **d、e** 术前 MRI 示 C3/4、C4/5、C5/6 椎间盘突出,脊髓神经受压 **f** 术后 3d 颈椎侧位 X 线片示 C2–C7 曲度为 18.68°,C3–C6 曲度为 13.66°, 内固定位置良好 **g** 术后 15 个月颈椎侧位 X 线片示 C2–C7 曲度为 14.93°,C3–C6 曲度为 10.42°, 手术节段椎间隙后方连续骨小梁形成 **h、i** 术后 15 个月颈椎过伸过屈位 X 线片示 C2–C7 活动度为 11.50°,C3–C6 活动度为 1.88°,C2/3、C3/4、C4/5、C5/6 活动度分别为 7.15°、0.07°、1.10°、0.03° **j** 术后 15 个月颈椎矢状位 CT 示手术节段后方连续骨小梁形成

Figure 3 A typical case of the FFF group, a 69–year–old woman underwent three–level ACDF **a** The preoperative lateral X–ray showed the C2–C7 Cobb angle was 19.79°, the C3–C6 Cobb angle was 13.12°, the osteophyte was formed at C4/5 and C5/6, and the intervertebral height was loss at C5/6 **b, c** The preoperative flexion and extension X–rays showed the C2–C7 ROM was 31.44°, the C3–C6 ROM was 22.78°, and the ROMs of C2/3, C3/4, C4/5 and C5/6 were 5.28°, 1.15°, 8.03° and 8.22°, respectively **d, e** The MRI showed disc herniation of C3/4, C4/5 and C5/6 **f** The lateral X–ray at 3 days postoperatively showed the C2–C7 Cobb angle was 18.68°, the C3–C6 Cobb angle was 13.66°, and the position of implants were good **g** The lateral X–ray at 15 months postoperatively showed the C2–C7 Cobb angle was 14.93°, the C3–C6 Cobb angle was 10.42°, and the continuous bridging bony trabeculae was formed at surgical levels **h, i** The flexion and extension X–rays at 15 months postoperatively showed the C2–C7 ROM was 11.50°, the C3–C6 ROM was 1.88°, and the ROMs of C2/3, C3/4, C4/5 and C5/6 were 7.15°, 0.07°, 1.10° and 0.03°, respectively **j** The CT at 15 months postoperatively showed continuous bridging bony trabeculae at surgical levels

丢失明显(P<0.05,最大丢失约 38%),三组对比两两均有显著性差异。本研究结果显示, 术后 3 个月、6 个月、12 个月及末次随访时,1A2F 组和 2A1F 组的颈椎 C2–7 活动度及手术节段活动度均显著高于 FFF 组,表明三节段 Hybrid 手术能够一定程度保留颈椎整体活动度及手术节段活动

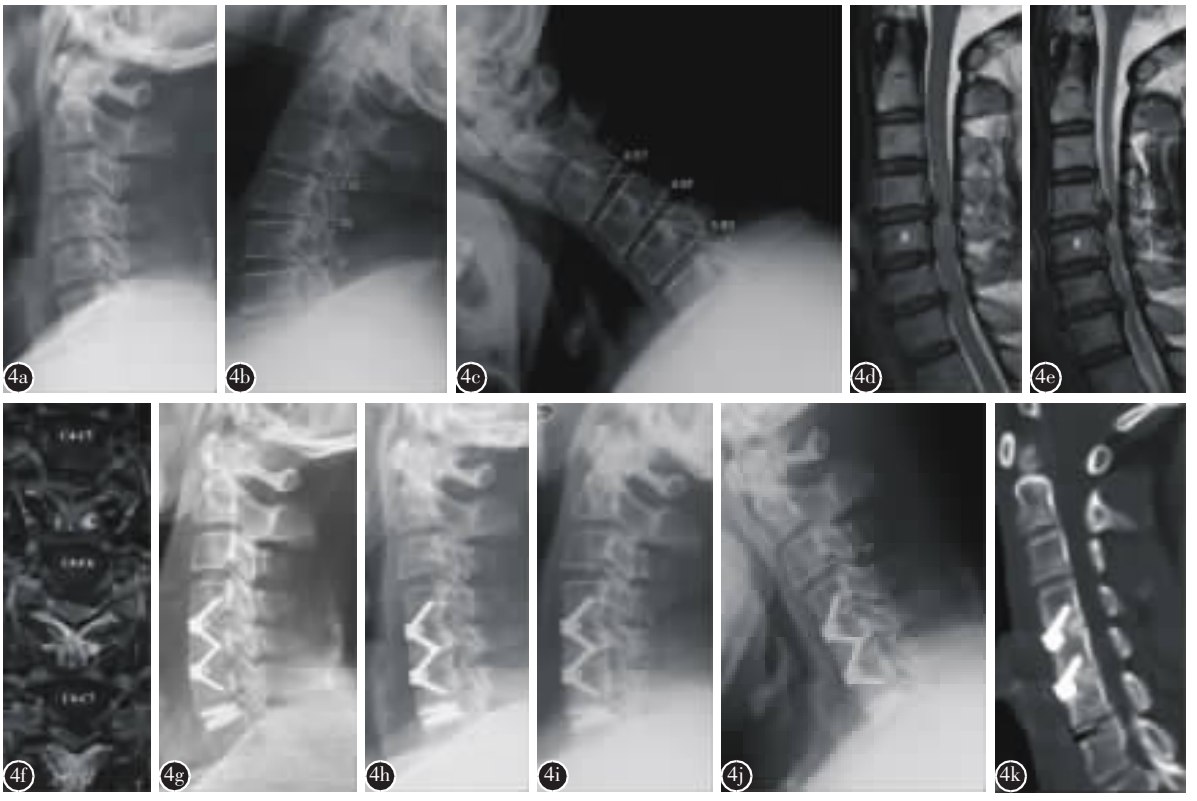

图 4 1A2F 组典型病例,59 岁男性患者 **a** 术前颈椎侧位 X 线片示 C2–C7 曲度为 12.85°,C4–C7 曲度为 14.38°,C4/5 椎间隙高度丢失伴有后方骨赘形成 **b**、**c** 术前颈椎过伸过屈位 X 线片示 C2–C7 活动度为 56.68°,C4–C7 活动度为 38.84°,C3/4、C4/5、C5/6、C6/7 活动度分别为 7.59°、12.00°、13.75°、5.47° **d~f** 术前 MRI 示 C4/5、C5/6、C6/7 椎间盘突出,脊髓神经受压 **g** 术后 3d 颈椎侧位 X 线片示 C2–C7 曲度为 23.26°,C4–C7 曲度为 20.74°,内固定位置良好 **h** 术后 18 个月颈椎侧位 X 线片示 C2–C7 曲度为 8.62°,C4–C7 曲度为 7.40°,C4/5、C5/6 椎间隙后方连续骨小梁形成 **i**、**j** 术后 18 个月颈椎过伸过屈位 X 线片示 C2–C7 活动度为 22.75°,C4–C7 活动度为 6.29°,C3/4、C4/5、C5/6、C6/7 活动度分别为 6.10°、0.40°、0.85°、5.20° **k** 术后 18 个月颈椎矢状位 CT 示 C4/5、C5/6 后方连续骨小梁形成

Figure 4 A typical case of the 1A2F group, a 59–year–old man underwent 1–level CDA and 2–level ACDF **a** The preoperative lateral X–ray showed the C2–C7 Cobb angle was 12.85°, the C4–C7 Cobb angle was 14.38°, the osteophyte was formed at C4/5, and the intervertebral height was loss **b, c** The preoperative flexion and extension X–rays showed the C2–C7 ROM was 56.68°, the C4–C7 ROM was 38.84°, and the ROMs of C3/4, C4/5, C5/6 and C6/7 were 7.59°, 12.00°, 13.75° and 5.47°, respectively **d–f** The MRI showed disc herniation of C4/5, C5/6 and C6/7 **g** The lateral X–ray at 3 days postoperatively showed the C2–C7 Cobb angle was 23.26°, the C4–C7 Cobb angle was 20.74°, and the position of implants were good **h** The lateral X–ray at 18 months postoperatively showed the C2–C7 Cobb angle was 8.62°, the C4–C7 Cobb angle was 7.40°, and the continuous bridging bony trabeculae was formed at C4/5 and C5/6 **i, j** The flexion and extension X–rays at 18 months postoperatively showed the C2–C7 ROM was 22.75°, the C4–C7 ROM was 6.29°, and the ROMs of C3/4, C4/5, C5/6 and C6/7 were 6.10°, 0.40°, 0.85° and 5.20°, respectively **k** The CT at 18 months postoperatively showed continuous bridging bony trabeculae at C4/5 and C5/6

度;此外,在术后 12 个月时 1A2F 组颈椎 C2–C7 活动度低于 2A1F 组,差异有统计学意义($P<0.05$),且术后 12 个月及末次随访时,1A2F 组手术节段活动度亦均低于 2A1F 组,差异有统计学意义($P<0.05$),表明 CDA 节段数量的增加能够保留更多的颈椎活动度;末次随访时 1A2F 组和 2A1F 组的颈椎 C2–C7 活动度无统计学差异,我们猜测可能与邻近节段活动度增加程度有关。但也有学者持不同意见。近期一项针对三节段颈椎 Hybrid 手术的 5 年随访研究[27]认为,Hybrid 手术虽有确切的临床疗效,对邻近节段活动度影响也小于 ACDF,但在保留颈椎活动度方面未表现出差异(末次随访时,ACDF 组 C2–C7 活动度丢失量为 16.2°±10°,1CDA+2ACDF 组为 15.8°±14.3°,

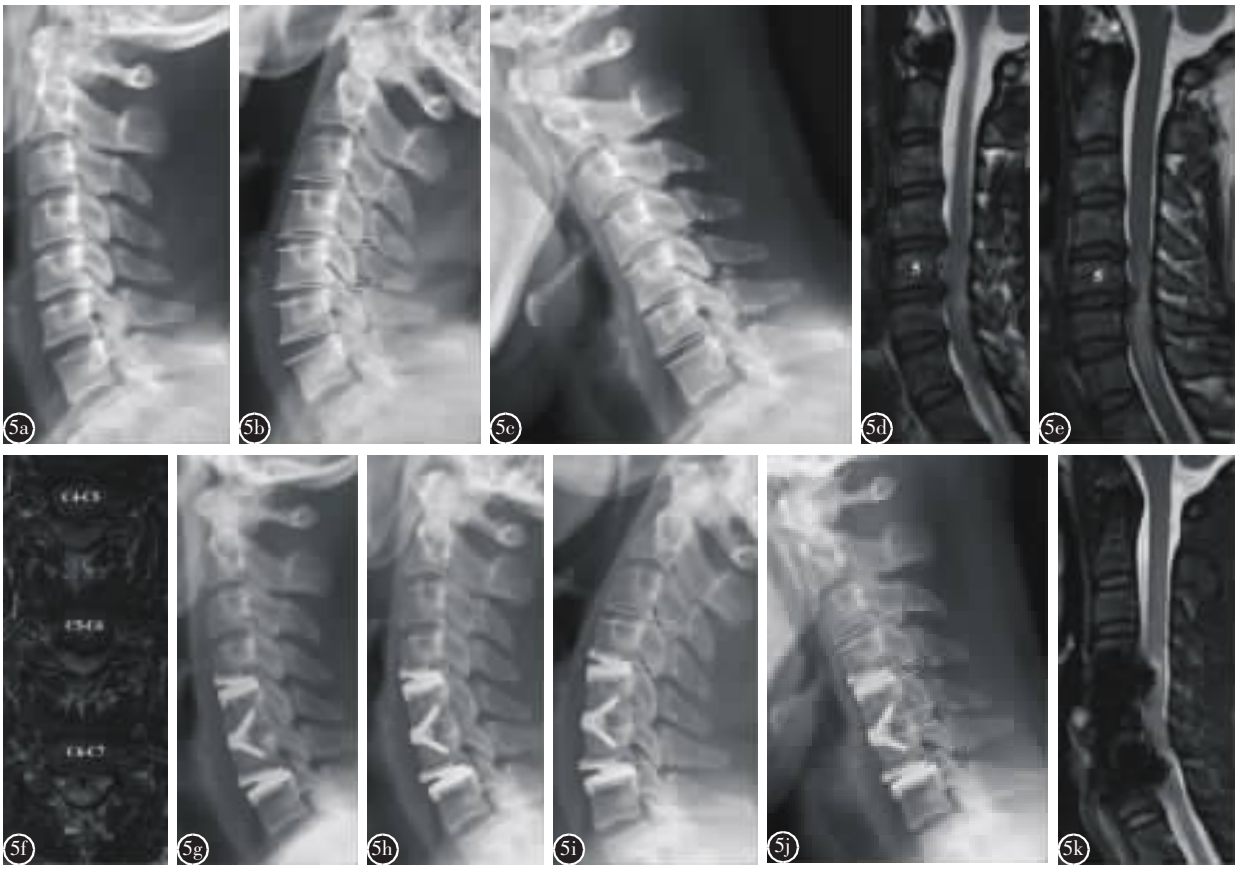

图 5 2A1F 组典型病例,41 岁女性患者 **a** 术前颈椎侧位 X 线片示 C2–C7 曲度为 17.27°,C4–C7 曲度为 11.54°,C5/6 椎间隙高度丢失伴有后方骨赘形成 **b**、**c** 术前颈椎过伸过屈位 X 线片示 C2–C7 活动度为 48.86°,C4–C7 活动度为 27.81°,C3/4、C4/5、C5/6、C6/7 活动度分别为 7.35°、6.23°、6.66°、7.37° **d~f** 术前 MRI 示 C4/5、C5/6、C6/7 椎间盘突出,脊髓神经受压 **g** 术后 3d 颈椎侧位 X 线片提示 C2–C7 曲度为 21.59°,C4–C7 曲度为 14.50°,内固定位置良好 **h** 术后 31 个月颈椎侧位 X 线片示 C2–C7 曲度为 27.46°,C4–C7 曲度为 15.82°,C4/5、C5/6 椎间隙后方连续骨小梁形成 **i**、**j** 术后 31 个月颈椎过伸过屈位 X 线片示 C2–C7 活动度为 38.54°,C4–C7 活动度为 23.93°,C3/4、C4/5、C5/6、C6/7 活动度分别为 8.35°、9.60°、1.02°、8.70° **k** 术后 31 个月颈椎 MRI 提示 C3/4、C7/T1 椎间盘信号良好

Figure 5 A typical case of the 2A1F group, a 41–year–old woman underwent 2–level CDA and 1–level ACDF **a** The preoperative lateral X–ray showed the C2–C7 Cobb angle was 17.27°, the C4–C7 Cobb angle was 11.54°, the osteophyte was formed at C5/6, and the intervertebral height was loss **b, c** The preoperative flexion and extension X–rays showed the C2–C7 ROM was 48.86°, the C4–C7 ROM was 27.81°, and the ROMs of C3/4, C4/5, C5/6 and C6/7 were 7.35°, 6.23°, 6.66° and 7.37°, respectively **d–f** The MRI showed disc herniation of C4/5, C5/6 and C6/7 **g** The lateral X–ray at 3 days postoperatively showed the C2–C7 Cobb angle was 21.59°, the C4–C7 Cobb angle was 14.50°, and the position of implants were good **h** The lateral X–ray at 31 months postoperatively showed the C2–C7 Cobb angle was 27.46°, the C4–C7 Cobb angle was 15.82°, and the continuous bridging bony trabeculae was formed at C5/6 **i, j** The flexion and extension X–rays at 31 months postoperatively showed the C2–C7 ROM was 38.54°, the C4–C7 ROM was 23.93°, and the ROMs of C3/4, C4/5, C5/6 and C6/7 were 8.35°, 9.60°, 1.02° and 8.70°, respectively **k** The MRI at 31 months postoperatively showed the signal of disc was normal at C3/4 and C7/T1

2CDA+1ACDF 组为 7.8°±8.5°,*P*=0.488),因此他们认为没必要行 CDA。但在他们的研究中,未进行三组数据的组内比较,2CDA+1ACDF 组活动度丢失量明显低于 ACDF 组。

Hybrid 手术对邻近节段可能具有一定的保护作用。虽然目前针对邻椎病的确切病因仍有争议,但多项生物力学研究均表明 Hybrid 手术邻近节段椎间盘所受应力小于 ACDF[16,28,29]。针对三节段颈椎 Hybrid 手术的临床报道也表明, Hybrid 手术组上下邻近节段的活动度增加程度明显低于

ACDF组[9,30]。这些研究初步揭示 Hybrid 手术可能能够通过降低邻近节段椎间盘应力、降低活动度增加程度等延缓邻近节段的退变。本研究结果显示术后 12 个月及末次随访时 ACDF 组上位邻近节段活动度增加程度明显高于 Hybrid 手术组,且末次随访时 1A2F 组上位邻近节段活动度增加程度亦高于 2A1F 组,表明 CDA 节段的增加对邻近节段的影响会随之降低。下一步,我们将根据 Hybrid 手术中 CDA 节段和 ACDF 节段不同位置关系进一步细化分组,探讨毗邻 CDA 节段和 ACDF 节段的邻近节段活动度增加的差异性。

现阶段针对 Hybrid 手术的研究仍有不足之处。首先,Hybrid 手术后颈部制动策略尚缺乏共识,文献报道中颈托佩戴时间术后 1 周至 3 个月不等,有学者主张长时间佩戴以提高植骨融合率,也有学者主张早期解除制动提高活动功能及康复效率[31]。本研究中,我们采用的是前 3 周在颈部制动的同时,适当进行功能锻炼,3 周后进行严格颈部制动至术后 3 个月。因为术后 3 周内为软组织修复期,适当的功能锻炼可能可以预防软组织瘢痕形成导致的人工颈椎间盘活动度丢失。3 周后可通过制动提高植骨融合率。目前我们正在针对 Hybrid 术后颈部制动策略进行研究。其次,颈椎 Hybrid 手术中,人工颈椎间盘假体所处的生物力学环境更为复杂,特别是三节段及以上 Hybrid 手术。现有人工颈椎间盘假体的初始设计多针对单节段手术,虽有部分假体已获 FDA 批准用于双节段 CDA 手术,但目前尚无针对颈椎 Hybrid 手术的人工颈椎间盘假体。未来针对这方面的研究仍有进一步深入的价值。

本研究存在一定的不足。首先,本研究为回顾性分析,可能存在一定的选择偏倚。其次,病变节段选择 CDA 或 ACDF 的指征存在一定的差异,虽然术前基线资料未表现出统计学差异,具有可比性,但本研究结论仍需大样本前瞻性随机对照研究进一步验证。

综上所述,我们认为三节段颈椎前路 Hybrid 手术具有不亚于三节段 ACDF 的临床疗效,其早期康复效率可能高于 ACDF;与 ACDF 相比,三节段颈椎前路 Hybrid 手术能够保留更多的颈椎活动度,降低对邻近节段活动的影响,且双节段 CDA+单节段 ACDF 手术方式比单节段 CDA+双节段 ACDF 手术方式更有优势。

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