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Editorial

Dear Readers,

We have completed another successful year of publication, filled with great milestones for the Turkish Medical Student Journal. As TMSJ completes its 12th year of publication, continuing its noble mission of including medical students and early career researchers at every stage of scientific publication, I complete my five years as an editor and two years as editor-in-chief of this journal.

Over the last five years, I've had the honor of working with the talented and dedicated editorial team and advisory board of TMSJ. It is thanks to my experiences and time working with them that I was able to grow as a person, researcher, and professional. I have met countless medical students, doctors, academics, and contributors whom I deeply appreciate for their passion and drive for scientific advancement. TMSJ has come to be an integral and unifying part of a community of people whom I trust will make the future a better place.

Now, I pass the torch to Ekin Lâl Akat. In the four years I've worked with her, she has shown her self-devotion and endless dedication to TMSJ's mission. She embodies the high ethical quality and scientific rigor TMSJ has shown to uphold, and I am in no doubt that she and the valued editorial team of TMSJ will work tirelessly for the advancement of medical research through supporting early career researchers.

I will always remember my years as an editor in TMSJ with fondness and joy. I am certain that our present and future editorial teams will uphold the standards and vision of this valuable journal.

I am grateful beyond words to everyone who has supported TMSJ in this journey, and I am excited and hopeful for the future they will create.

I extend my warmest wishes and bid you a fond farewell.

Sıla Ece Tiryaki

Editor-in-Chief, Turkish Medical Student Journal

Trakya University School of Medicine, Edirne, TÜRKİYE

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THE ROLE OF STEM CELLS IN ATHEROSCLEROSIS TREATMENT AND FUTURE PERSPECTIVES

İ Sıla Başak Gök¹, İ Kayra Kılıç¹, İ Yiğit Balıkçı¹, İ Cansel Şahin¹, İ Aleyna Kılıç¹, İ Muhammet Gürdoğan²

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ABSTRACT

Atherosclerosis remains a primary driver of global cardiovascular morbidity and mortality, characterized by the progressive accumulation of lipids and inflammatory infiltrates within the arterial wall. This multifaceted pathology originates with endothelial dysfunction, particularly in regions subjected to disturbed hemodynamic flow, and evolves into the formation of unstable plaques that frequently culminate in acute clinical events such as myocardial infarction and stroke. While current pharmacological interventions—primarily statins and antiplatelet agents—effectively reduce mortality, they exhibit significant limitations in stabilizing advanced lesions and preventing post-interventional restenosis. Consequently, stem cell-based therapies have emerged as a transformative strategy in regenerative medicine, aiming to modulate the disease's underlying cellular mechanisms rather than merely addressing its clinical manifestations. Various cell populations, including mesenchymal stem cells, adipose-derived stem cells, and induced pluripotent stem cells, are currently being investigated for their roles in vascular repair, mediated through immunomodulation, endothelial restoration, and exosome-driven paracrine signaling. Although preliminary findings indicate the safety of these interventions, the successful translation of such regenerative approaches into routine clinical practice necessitates the standardization of protocols and the execution of large-scale clinical trials to establish long-term efficacy and stability.

Keywords: Angiogenesis, atorvastatin, induced pluripotent stem cells, vascular endothelial growth factors

INTRODUCTION

Atherosclerosis is the chronic inflammation that causes the vast majority of cardiovascular disease and mortality globally. It is pathologically defined by the formation of atheromatous plaques consisting of a fibrous cap over a necrotic core that underlie most fatal cardiovascular events, including myocardial infarction, stroke, and peripheral arterial disease (1, 2).

The disease is initiated by endothelial dysfunction, particularly in arterial regions of disturbed hemodynamic flow. This dysfunction reduces the synthesis of beneficial vasodilators, such as nitric oxide (NO), while upregulating pro-atherogenic adhesion molecules, including vascular cell adhesion molecule 1 (VCAM-1) and intercellular adhesion molecule 1 (ICAM-1). This is followed by the accumulation and oxidation of low-density lipoproteins (LDL) within the subendothelial space, a defining event in

the process. This mechanism recruits circulating monocytes, which travel into the intima, develop into macrophages, and internalize modified LDL via scavenger receptors (such as CD36) to form foam cells. Persistent inflammation mediated by the NOD-like receptor family pyrin domain containing 3 (NLRP3) inflammasome accelerates foam cell death and disrupts the efferocytosis clearance process. This cycle fuels the expansion of the plaque's pro-thrombotic necrotic core (2-4).

The most severe clinical outcomes, such as acute coronary syndromes, are precipitated by plaque rupture (particularly of vulnerable, thin-capped plaques) or erosion, which leads to acute thrombosis (5). Although conventional therapies, including statins and antiplatelet agents, have significantly reduced cardiovascular mortality; their utility is limited. These treatments can have severe effects, such as statin-induced myopathy, and



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often fail to sufficiently stabilize advanced plaques or prevent post-interventional restenosis (6). Given these limitations, there is a critical need for innovative therapeutic approaches. Stem cell therapies have thus been recognized as a revolutionary strategy for overcoming these challenges. Unlike conventional therapies, stem cells have the unique ability to target the root cause of atherosclerosis by stabilizing plaques and restoring damaged vessels. This changes the treatment paradigm from managing the disease to seeking a biological cure.

The Therapeutic Potential of Mesenchymal Stem Cells in Atherosclerosis

Given that chronic inflammation is a major cause of atherosclerosis, mesenchymal stem cells (MSCs) have emerged as a highly promising treatment option. They target different phases of disease development via potent immunomodulatory, regenerative, and metabolic regulatory pathways (7). The systemic administration of MSCs significantly reduces the inflammatory response following Ischemia, resulting in a reduction in infarct size (8). A central mechanism of action involves modulating central immune cells and pathways; for instance, human amniotic-derived MSCs reduce atherosclerosis by shifting the cytokine environment from pro-inflammatory to anti-inflammatory, notably by reducing tumor necrosis factor alpha (TNF- α) and increasing interleukin (IL)-10 (9). MSCs also directly affect T-cell function by inhibiting T-cell proliferation and facilitating the essential conversion from pro-inflammatory T helper 1 and T helper 17 cells to anti-inflammatory regulatory T-cells (Tregs) with high IL-10 production (10-12). Specifically, MSC-derived microRNA 125b-1-3p induces T-cell apoptosis by downregulating the T-cell survival gene *B-cell lymphoma/leukemia 11B* (13).

Beyond systemic immunomodulatory effects, MSCs and their products directly target the vascular endothelial dysfunction triggering atherosclerosis. MSC-derived exosomes loaded with miR-145 suppress leukocyte transendothelial migration by reducing junctional-adhesion molecule-A expression, thereby strengthening endothelial barrier integrity (14). Furthermore, MSC-derived extracellular vesicles reverse endothelial-to-mesenchymal transition (EndMT), while miR-126 mimics can further enhance MSC proliferation, migration, and endothelial differentiation, facilitating vascular repair (15, 16). Alongside these mechanisms, MSC immunomodulatory properties influence lipid metabolism, leading to a significant decrease in plasma cholesterol concentrations primarily through a reduction in very low-density lipoprotein secretion (17). Crucially, MSC therapy promotes plaque stabilization, the primary determinant of acute cardiovascular events. This stabilization is driven by the aforementioned cytokine microenvironment shift (decreased TNF- α , increased IL-10) (18). MSCs are specifically attracted to atherosclerotic plaques, and once localized, their exosomes directly modulate plaque biology (19). Bone marrow MSC exosomes, for example, promote plaque stabilization by inhibiting pyroptosis—a highly inflammatory form of cell

death—indicated by decreased expression of NLRP3, caspase-1, and gasdermin D (20).

Therapeutic Targeting of the Endothelium and Its Progenitor Cells in Atherosclerosis

Endothelial progenitor cells are essential for vascular repair and re-endothelialization. They have the ability to differentiate into functional endothelial cells (ECs), promoting neovascularization and replacing damaged endothelium, a therapeutic potential supported by clinical applications in cardiovascular and ischemic diseases (21). However, in atherogenic environments, this regenerative capacity is overwhelmed, and mature ECs undergo a pathological conversion. Instead of promoting vascular health, ECs maintain inflammation by upregulating GATA binding protein 6, which directly targets cytidine/uridine monophosphate kinase 2 to activate the NLRP3 inflammasome and increase IL-1 β production, thereby driving monocyte recruitment and vascular inflammation (22). Furthermore, ECs can promote plaque formation by acquiring a foam cell-like phenotype, a transition characterized by the excessive accumulation of lipid droplets and the subsequent expression of adhesion molecules such as VCAM-1 (23). This inflammatory environment eventually drives EndMT, where ECs lose their healthy phenotype by degrading their intercellular junctions, acquire invasive mesenchymal properties, and promote fibrosis and vascular calcification (24). Emerging therapeutic strategies aim to reverse this pathological transition. Targeted interventions that repair the endothelial barrier can inhibit immune cell infiltration and reverse EndMT, restoring the vessel to a healthy phenotype. This restorative potential is further supported by recent genetic reprogramming strategies, such as OSK transcription factor overexpression, which reverses cellular senescence and inhibits pro-atherosclerotic EndMT (25).

The Therapeutic Role of Hematopoietic Stem Cells in Atherosclerosis

Hematopoietic stem cells (HSCs) are considered the prime progenitors of all circulating blood and immune cells, thus regulating the body's inflammatory response. However, recent breakthroughs suggest that HSCs are now recognized as key drivers of atherosclerosis. Evidence suggests that systemic conditions, such as hypercholesterolemia, can directly "prime" HSCs to become inflammatory cells (26). This pathophysiology can be best understood in the context of clonal hematopoiesis, where somatic mutations (e.g., tet methylcytosine dioxygenase 2) cause the clonal expansion of HSCs. This has been directly associated with the acceleration of atherosclerosis, primarily due to mechanisms such as the activation of the NLRP3 inflammasome (27, 28). Therefore, the focus of therapy has shifted from regeneration to the regulation of this pathologically aberrant behavior. The natural plasticity of the hematopoietic system makes this possible; for example, exercise can "reprogram" progenitors to reduce the inflammatory response (29). Thus, targeting the bone marrow

niche to alter HSC differentiation pathways is emerging as a novel therapeutic strategy.

The Therapeutic Role of Adipose-Derived Stem Cells in Atherosclerosis

Adipose-derived stem cells (ADSCs) are a type of multipotent MSCs that come from the stromal vascular fraction of fat tissue. They've gotten a lot of attention because they naturally have antioxidant, anti-inflammatory, and anti-apoptotic qualities. The main way ADSCs work is through their strong paracrine activity. Conditioned medium from ADSCs helped reduce atherosclerosis in low-density lipoprotein receptor-/- mice, mainly by reducing the inflammation in their blood vessels. The changes were linked more to reduced cell adhesion molecules and macrophage infiltration, rather than shifts in serum lipids. This effect happened because the mitogen-activated protein kinase and nuclear factor- κ B signaling pathways were turned down, and hepatocyte growth factor (HGF) was found to be an important secreted factor (30). Similarly, in ischemia-reperfusion injury models, ADSCs counteract oxidative stress by overexpressing antioxidant enzymes ((NAD(P)H quinone oxidoreductase 1, heme oxygenase-1), concurrently decreasing the expression of inflammatory mediators such as VCAM-1, ICAM-1, and TNF- α (31).

In addition to their secretory components, ADSCs possess strong immunomodulatory properties. They stimulate the production of regulatory Tregs and the differentiation of macrophages into the anti-inflammatory M2 phenotype through both direct and indirect signaling. This leads to a beneficial cytokine profile, decreasing pro-inflammatory TNF- α and IL-1 β , while increasing anti-inflammatory IL-10 (21).

Moreover, ADSCs possess strong regenerative properties. They have been shown to differentiate into viable ECs, expressing markers such as CD34, platelet endothelial cell adhesion molecule, and vascular endothelial-cadherin (32). Their differentiation capacity, along with their secretion of angiogenic factors (vascular endothelial growth factor, HGF), enables ADSCs to directly participate in neovascularization and the repair of the injured endothelial lining (21).

The Therapeutic Role of Induced Pluripotent Stem Cells in Atherosclerosis

By producing patient-specific induced pluripotent stem cell-derived ECs (iPSC-ECs), iPSCs have become a game-changing tool in cardiovascular medicine (33). Researchers can now produce high-fidelity, physiologically relevant models thanks to this technology. It has been confirmed that these iPSC-ECs are functionally competent and can appropriately react to intricate hemodynamic and inflammatory cues. For instance, they upregulate protective factors such as KLF2, KLF4, and endothelial nitric oxide synthase under atheroprotective shear stress. On the other hand, pro-inflammatory stimuli accurately mimic the start of vascular inflammation by inducing the expression of adhesion molecules like ICAM-1 and E-selectin (34).

Induced pluripotent stem cells are an essential preclinical tool because they enable researchers to examine disease pathways and test treatments on a patient's own cells. Research on accelerated atherosclerosis in relation to Hutchinson-Gilford Progeria Syndrome (HGPS) provides the finest example of this utility. By using HGPS-derived iPSC-ECs, researchers were able to test investigational drugs (like Everolimus) and show a partial restoration of endothelial function and NO production in cells with that specific disease background (35).

Consequently, the therapeutic role of iPSCs in atherosclerosis is currently defined not by direct cellular transplantation, but by their indispensable function as a discovery engine for identifying and validating new pharmacological strategies.

Stem Cell Mechanisms in Atherosclerosis Therapy

Stem cell therapies intervene in the atherosclerotic process through several key, often overlapping, mechanisms (Figure 1) (18,25,36-39).

Clinical Translation and Future Perspectives

Early clinical trials of MSCs have shown encouraging results in terms of safety and efficacy. For example, Phase I clinical trials of autologous adipose-derived MSCs (AD-MSCs) showed marked attenuation of key pro-inflammatory cytokines such as IL-1 α , IL-6, and TNF- α in patients with systemic inflammation, with no adverse effects reported (40). These findings are consistent with those of other diseases, such as HGPS and congestive heart failure, in which MSC infusions were found to reduce arterial stiffness and improve cardiac function (41-43). While these findings suggest the therapeutic potential of MSCs, the challenge of long-term efficacy, particularly in atherosclerosis, still persists. A key issue is the variability of existing studies in terms of cell type, administration routes, and patient selection, making direct comparison of results difficult (Table 1). Furthermore, it is important to emphasize that the current clinical management of atherosclerosis heavily relies on established pharmacological interventions, as outlined in the contemporary ACC/AHA and ESC guidelines for the management of dyslipidemias and cardiovascular risk. Due to the limited availability of robust human data and the absence of large-scale randomized phase III clinical trials, stem cell therapies remain investigational and have not yet been incorporated into these major guideline recommendations or routine clinical practice. Looking ahead, the successful translation of stem cell therapy into the clinical setting must address several key issues. The foremost among these is the lack of standardized protocols for cell processing and administration, which is a limitation in terms of reproducibility (37).

Moreover, long-term safety data must be carefully evaluated, particularly in terms of the genomic integrity and tumorigenicity of iPSCs (44). To address these limitations, there is an increasing trend in research towards cell-free therapies such as MSC exosomes although the mechanisms and targeted delivery of these exosomes need further optimization (45). Moreover, to maximize the therapeutic potential, there may be a need

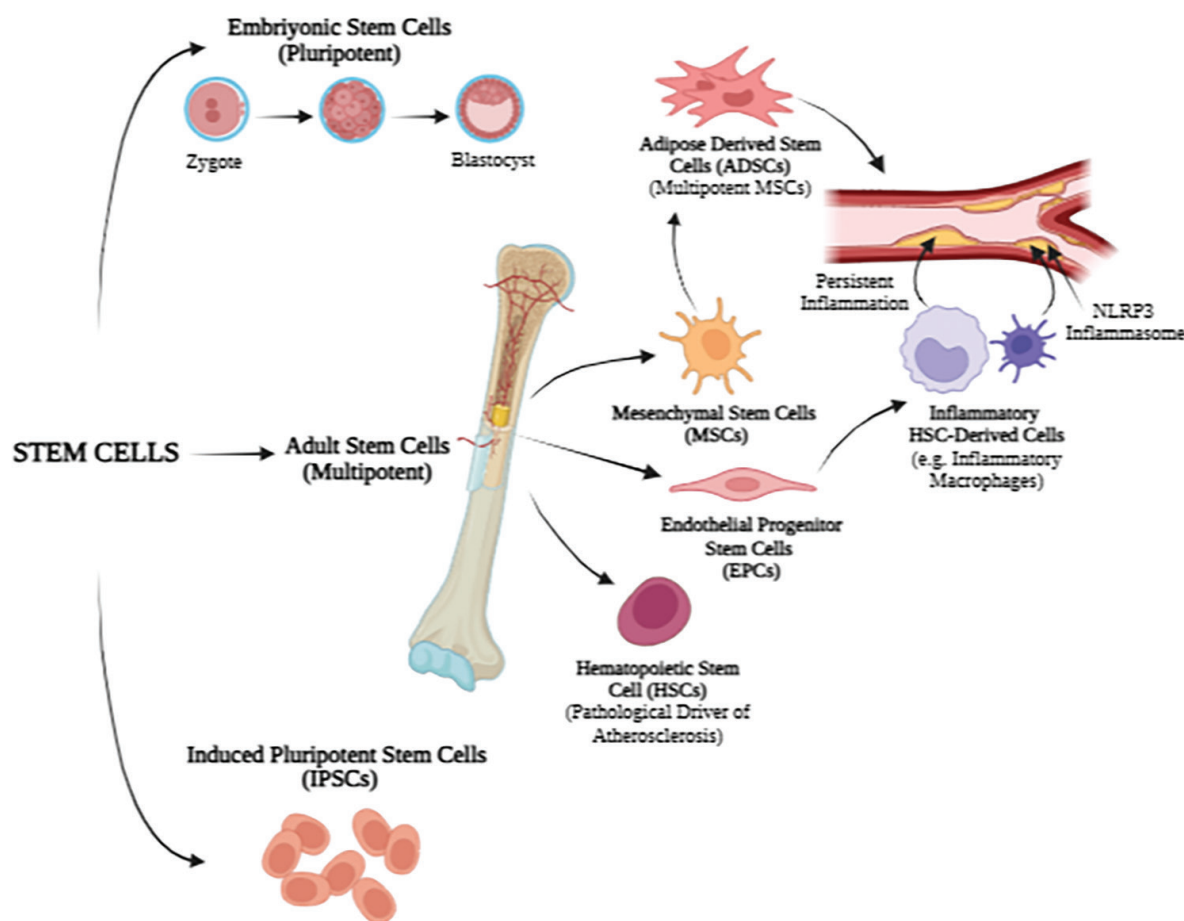


Figure 1: Overview of different stem cell types. **1. Immunomodulation:** MSCs and ADSCs are strong anti-inflammatory agents. They do this by inhibiting key signaling pathways such as NF- κ B, which in turn changes the cytokine environment from pro-inflammatory (TNF- α) to anti-inflammatory (IL-10) (18). **2. Endothelial Repair:** These cells contribute to the repair of the damaged inner lining of blood vessels. This is achieved by enhancing the integrity of the endothelial layer to prevent leukocytes from migrating through and potentially reversing the detrimental process of endothelial-to-mesenchymal transition (25). **3. Plaque Stabilization:** MSCs are attracted to the site of injury. At the site, they contribute to the stabilization of unstable plaques by inhibiting pyroptosis (an extremely pro-inflammatory form of cell death) by suppressing the NLRP3 inflammasome and caspase-1 activation, and by modulating metabolic gene expression in the plaque (36). **4. Regeneration and Angiogenesis:** By secreting angiogenic factors (HGF, VEGF) and having the ability to differentiate into functional endothelial cells, ADSCs and MSCs contribute to neovascularization and the regeneration of damaged tissue (37). **5. Exosome-Mediated Signaling:** Stem cells release exosomes that act as paracrine messengers. These vesicles deliver regulatory cargo, such as microRNAs (e.g., miR-145, miR-125b), which can enhance endothelial barrier integrity, induce T-cell apoptosis, or suppress inflammation by activating other pathways (e.g., SIRT1) (38). **6. iPSC-Based Discovery:** iPSCs serve a different role as a preclinical discovery engine. They provide high-fidelity, patient-specific models (iPSC-ECs) essential for dissecting disease mechanisms and validating new pharmacological strategies (39).

MSCs: Mesenchymal stem cells, ADSCs: Adipose-derived stem cells, TNF- α : Tumor necrosis factor alpha, IL-10: Interleukin-10, HGF: Hepatocyte growth factor, iPSC-ECs: Induced pluripotent stem cell-derived-endothelial cells, NF- κ B: Nuclear factor- κ B, VEGF: Vascular endothelial growth factor, NLRP3: NOD-like receptor family pyrin domain containing 3, SIRT1: Sirtuin 1.

Table 1: Summary of clinical studies evaluating the effects of stem cell-based therapies.

Cell type	Study population	Principal findings
Autologous adipose tissue-derived stem cells	Patients with aging-related low-grade inflammation	<ul style="list-style-type: none"> • Attenuation of pro-inflammatory cytokines such as IL-1α, IL-6, and TNF-α • No adverse effects reported
Allogeneic bone marrow-derived clonal MSCs	Patient with Hutchinson-Gilford Progeria Syndrome	<ul style="list-style-type: none"> • Reduced arterial stiffness • Decreased levels of sICAM-1, IL-18, and MCP-1. • Long-term efficacy limited by continued disease progression.
Allogeneic hMSCs delivered by transendocardial injections oto-hMSC ve allo-hMSC	Patients with nonischemic dilated cardiomyopathy	<ul style="list-style-type: none"> • Improved cardiac function • Reduced infarct size • Improved ventricular remodeling • Enhanced neovascularization
Allogeneic and autologous bone marrow-derived human mesenchymal stem cells	Patients with nonischemic dilated cardiomyopathy	<ul style="list-style-type: none"> • Greater improvement in ejection fraction • Improved 6-minute walk distance and endothelial function • Reduced pro-inflammatory TNF-α levels

allo-hMSC: Allogeneic human mesenchymal stem cells, hMSCs: Human mesenchymal stem cells, IL-1 α : Interleukin 1 alpha, IL-6: Interleukin 6, IL-18: Interleukin 18, MCP-1: Monocyte chemoattractant protein-1, MSC: Mesenchymal stem cells, oto-hMSC: Autologous human mesenchymal stem cells, sICAM-1: Soluble intercellular adhesion molecule-1, TNF- α : Tumor necrosis factor alpha.

for combination therapies that combine stem cells with conventional anti-inflammatory and lipid-lowering therapies (46). Ultimately, advancements in iPSC technology hold the key to personalized medicine, enabling the creation of patient-specific disease models to target unique molecular pathways (47).

CONCLUSION

The integration of stem cell biology into the management of atherosclerosis represents a significant advancement in cardiovascular medicine. By targeting the fundamental mechanisms of inflammation and endothelial decay, stem cell-based therapies offer a potential for disease modification that exceeds the capabilities of current pharmacological standards. However, despite encouraging preclinical and early clinical data, stem cell therapy for atherosclerosis remains investigational and has not yet entered routine clinical practice. The path to clinical integration still requires the standardization of isolation protocols, long-term safety monitoring, and the development of targeted delivery systems to ensure localized efficacy without systemic adverse effects.

Footnotes

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EXTENSIVE CERVICOTHORACIC SYRINGOMYELIA ASSOCIATED WITH BORDERLINE TONSILLAR DESCENT: A CASE REPORT OF POSTERIOR FOSSA DECOMPRESSION

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ABSTRACT

Chiari malformation type I is a structural disorder characterised by herniation of the cerebellar tonsils through the foramen magnum, frequently associated with syringomyelia. Although a descent of at least 5 mm is conventionally required for diagnosis, lesser degrees may be clinically significant when cerebrospinal fluid dynamics at the craniocervical junction are disturbed. A 40-year-old female patient presented with cervical and left shoulder pain persisting for two months, without motor or sensory deficit. Cervical magnetic resonance imaging revealed a crowded posterior fossa, tonsillar herniation of only 4.5 mm below the basion-opisthion line, reduced subarachnoid spaces at the craniocervical junction, and a 130 mm hydrosyringomyelia cavity extending from the odontoid process to T2, 9×12 mm at its widest, with cord expansion and perisyrinx T2-weighted hyperintensity suggestive of chronic spinal cord injury. Surgery was indicated by the extent of the syrinx and the risk of irreversible cord injury, rather than pain alone. The patient underwent posterior fossa decompression consisting of suboccipital craniectomy, C1 posterior arch excision, and duraplasty. The early postoperative course was uneventful; a minor superficial wound problem was managed conservatively during follow-up. At 18 months her pain had improved, the neurological examination was unchanged, and serial imaging showed sustained decompression with syrinx regression. This case suggests that craniocervical morphology and cerebrospinal fluid flow, rather than the millimetric extent of tonsillar descent alone, should guide assessment and the decision to operate.

Keywords: Case report, Chiari malformation type I, posterior cranial fossa, surgical decompression, syringomyelia

INTRODUCTION

Chiari malformation type I (CM-I) is a structural disorder of the posterior cranial fossa characterised by the herniation of the cerebellar tonsils through the foramen magnum (1, 2). Hans von Chiari first described and classified these malformations according to the degree of tonsillar herniation at the end of the 19th century (2, 3). CM-I is the most prevalent subtype, with a reported incidence ranging from 1 in 1,000 to 1 in

5,000 and is relatively uncommon in the adult population (2, 4). Reported prevalence, age at presentation and access to specialist care also vary across sociodemographic groups (5). Several pathophysiological mechanisms have been proposed: the predominant hypothesis attributes CM-I to an aberrantly small posterior cranial fossa in which the neural contents are crowded and herniate into the spinal canal (3); others suggest that excessive cerebellar growth during the embryonic period



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displaces the tonsils caudally (3); and a further theory implicates mechanical downward traction of the brainstem and cerebellum by the filum terminale (3). Clinically, the condition spans a wide spectrum extending from entirely asymptomatic individuals to patients with serious neurological impairment (2, 6). Although nausea, dysphagia, apnoea, clonus, cerebellar signs, drop attacks, muscle atrophy, and dysphonia have all been reported, cervical pain and headache remain the most frequently observed presenting complaints (1, 2, 6, 7).

Diagnosis relies on a combination of clinical history, neurological examination, and magnetic resonance imaging (MRI) of the craniocervical junction (3, 8). A tonsillar descent of at least 5 mm below the basion-opisthion line is conventionally applied as the radiological criterion. However, this threshold is arbitrary and does not by itself determine clinical relevance: herniations of 3-5 mm may be symptomatic when accompanied by syringomyelia, obliteration of the retrocerebellar cerebrospinal fluid (CSF) spaces, or an unfavourable posterior fossa morphology (7-9). Surgical intervention is the primary treatment, and accurate patient selection combined with an appropriate operative strategy is associated with a high rate of symptomatic improvement which is consistent with the potentially reversible nature of the condition (3). Nevertheless, the natural history of CM-I remains incompletely understood, and ongoing clinical and imaging research continues to refine current knowledge of the disease (2). We present an adult patient in whom an extensive cervicothoracic syrinx was associated with a tonsillar descent of only 4.5 mm, in order to illustrate that the clinical significance of Chiari-related pathology cannot be judged by the millimetric extent of tonsillar herniation alone, and that management should follow an individualised assessment integrating the clinical findings, posterior fossa crowding, craniocervical junction anatomy, syrinx burden and the probable disturbance of CSF dynamics.

CASE REPORT

A 40-year-old female patient presented to Trakya University Hospital Department of Neurosurgery with complaints of neck pain and left shoulder pain persisting for two months. Her medical history included hypothyroidism managed with levothyroxine (Euthyrox; Merck, Darmstadt, Germany) at 25 µg daily, increased to twice daily on weekends; two prior caesarean sections; and a previous right wrist surgery. Her family history was unremarkable.

On neurological examination the patient was alert and fully orientated, and the cranial nerve examination was intact. Motor examination revealed no focal weakness, with muscle strength graded 5/5 in all extremity muscle groups. Sensory examination, including light touch, pinprick, and vibration, was unremarkable, and there was no suspended or dissociated sensory loss. Mild hypertonia was noted in the extremities. Deep tendon reflexes were normoactive and symmetrical (2+/2+ in both upper and lower extremities), plantar responses were flexor bilaterally, and neither the Hoffmann's sign nor clonus could be elicited.

Cerebellar examination demonstrated no dysmetria or dysidiadochokinesia, and the Romberg test was negative. Gait was normal. Spurling's test was negative bilaterally. The patient described occasional stress urinary incontinence triggered by coughing and sneezing; this symptom was not investigated further with urological, gynaecological or urodynamic assessment.

Laboratory investigations revealed no abnormalities. A cervical MRI study, obtained at Trakya University Faculty of Medicine (14.05.2024), demonstrated a crowded posterior fossa with the cerebellar tonsils herniated 4.5 mm below the basion-opisthion line. A decrease in the anterior and posterior subarachnoid spaces with cord expansion was observed at the C2 vertebral level. In addition, a hydrosyringomyelia cavity extending from the level of the odontoid process to T2, spanning a 130 mm segment and reaching a maximum diameter of 9×12 mm at C2, was identified, causing significant cord expansion and exhibiting T2-weighted hyperintensity in the spinal cord surrounding the syrinx, suggestive of chronic spinal cord injury (Figure 1). The tonsillar descent was therefore below the conventional 5 mm threshold, and the diagnosis was not based on this single measurement. CM-I with extensive cervicothoracic hydrosyringomyelia was diagnosed on the combined basis of posterior fossa crowding, effacement of the subarachnoid spaces at the craniocervical junction suggestive of impaired CSF flow, the craniocaudal extent of the syrinx, the associated cord expansion, the perisyrinx signal change, and the clinical presentation.

The principal indication for surgery was not the pain itself. The patient had neither motor nor sensory deficit, and her symptoms in isolation would not have mandated operative treatment. Decompression was recommended because of the craniocaudal extent of the syrinx, the degree of cord expansion, the perisyrinx signal change indicating established cord injury, and the consequent risk of progressive and potentially irreversible myelopathy should the underlying obstruction to CSF flow be left untreated. Posterior fossa decompression was recommended, and the patient was counselled regarding the procedure and its associated risks.

The patient underwent surgery on 26 August 2024 under general anaesthesia. She was positioned prone with the head secured in a Mayfield clamp in flexion. Although a horseshoe headrest is an equally acceptable and less invasive alternative for this procedure, the Mayfield clamp was selected to provide rigid fixation and a reproducible degree of flexion during microsurgical dural work. A midline incision of approximately 10 cm was made, extending from 1 cm above theinion to the C2 spinous process. The nuchal fascia was opened along the midline using monopolar cautery, and the nuchal muscles were subperiosteally stripped from the occipital bone. The occipital bone, the posterior rim of the foramen magnum, and the C1 posterior arch were exposed. The operating microscope was introduced. Using a high-speed drill and Kerrison rongeurs, a suboccipital craniectomy measuring approximately 2×4 cm

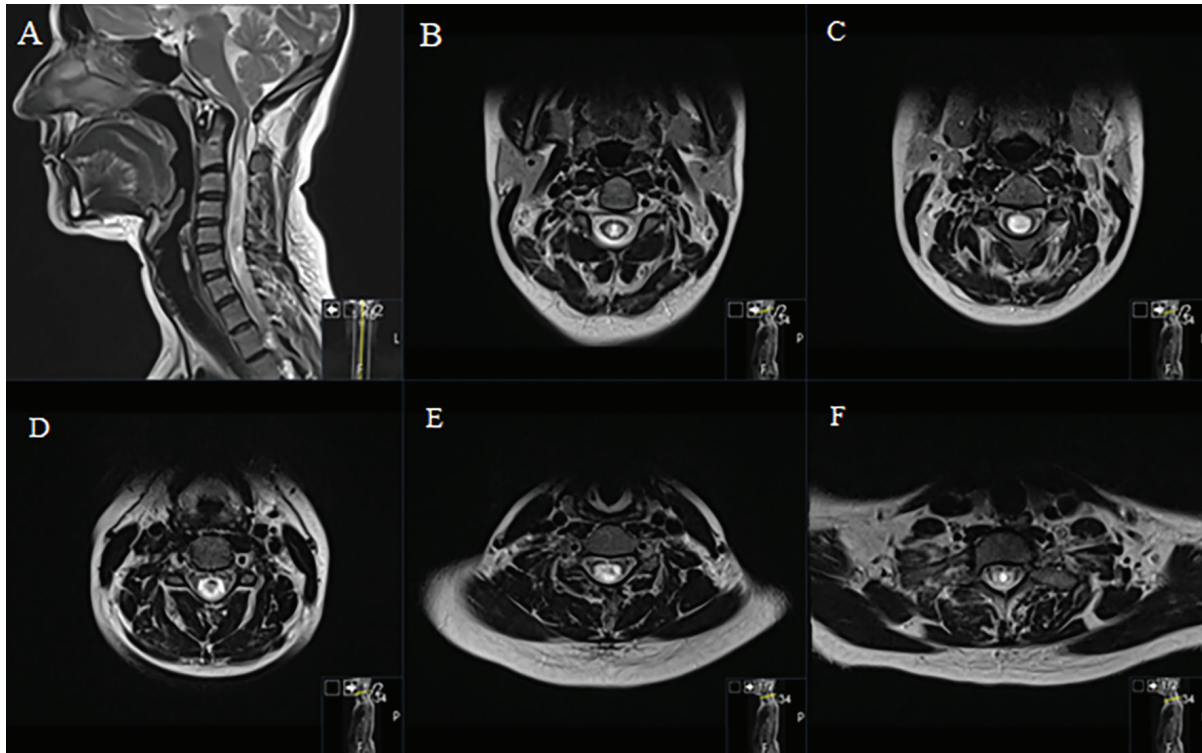


Figure 1: Preoperative cervical MRI. (A) Sagittal T2-weighted image demonstrating cerebellar tonsillar herniation below the foramen magnum and extensive hydrosyringomyelia extending from the odontoid process to T2. (B-F) Axial T2-weighted images between C2-C7 levels showing the syrinx cavity (9×12 mm) with surrounding T2-weighted hyperintensity.

MRI: Magnetic resonance imaging.

and extending roughly 2 cm lateral to the midline bilaterally was performed, along with excision of the C1 posterior arch. The posterior borders of the foramen magnum were further widened with Kerrison rongeurs.

The occipital sinus at the posterior rim of the foramen magnum was coagulated with bipolar diathermy and divided under microscopic vision before the dural leaves were reflected. The dura and overlying fibrotic bands were opened down to the C2 level using a blunt-tipped hook and a no. 11 blade. The subarachnoid membranes appeared fibrotic; CSF exit was confirmed from several millimetric openings, and the cisterna magna was adequately decompressed. A synthetic dura graft, approximately 3.5×1 cm and fashioned in a fish-mouth configuration, was sutured to the dural edges with 4-0 Vicryl in a watertight fashion. An autologous fascial or aponeurotic graft harvested from the operative field would have been an equally appropriate, and in several respects preferable, alternative; a synthetic substitute was used in this patient according to the preference of the operating surgeon and the graft material available in theatre at the time of operation. A small CSF leak at the uppermost suture line was reinforced with a muscle graft secured by a separate suture, followed by application of tissue adhesive and a thin layer of Spongostan. The nuchal muscles, fascia, and periosteum were closed with 2-0 Vicryl, and the remaining layers were approximated anatomically. The operative duration was 2 hours and 45 minutes, and blood loss

was minimal (<50 mL). No intraoperative complications were encountered. The patient was extubated uneventfully and transferred to the ward in stable condition.

The early postoperative course was uneventful. Neurological examination findings remained stable. The patient was mobilised on the first postoperative day and discharged in good condition. An early postoperative cervical MRI, obtained on the second postoperative day, confirmed adequate decompression of the posterior fossa (Figure 2).

At the seven-month follow-up visit in March 2025, the patient reported improvement in her cervical symptoms. Examination of the surgical wound revealed a millimetric crust, which was excised; a small wound opening was managed with local wound care and topical mupirocin ointment (Thiocilline; Abdi İbrahim, İstanbul, Türkiye). This minor superficial wound problem resolved completely with conservative treatment and required neither surgical revision nor systemic antibiotic therapy. A follow-up cervical MRI at six months postoperatively demonstrated satisfactory decompression of the craniocervical junction and interval reduction of the syrinx cavity (Figure 3). Measured on the sagittal T2-weighted sequence and on the axial section at C2, corresponding to the levels used preoperatively, the syrinx measured 95 mm in length and 1.5×2.5 mm at C2, compared with 130 mm and 9×12 mm before surgery. The patient was advised to undergo a repeat cervical MRI at one year postoperatively.

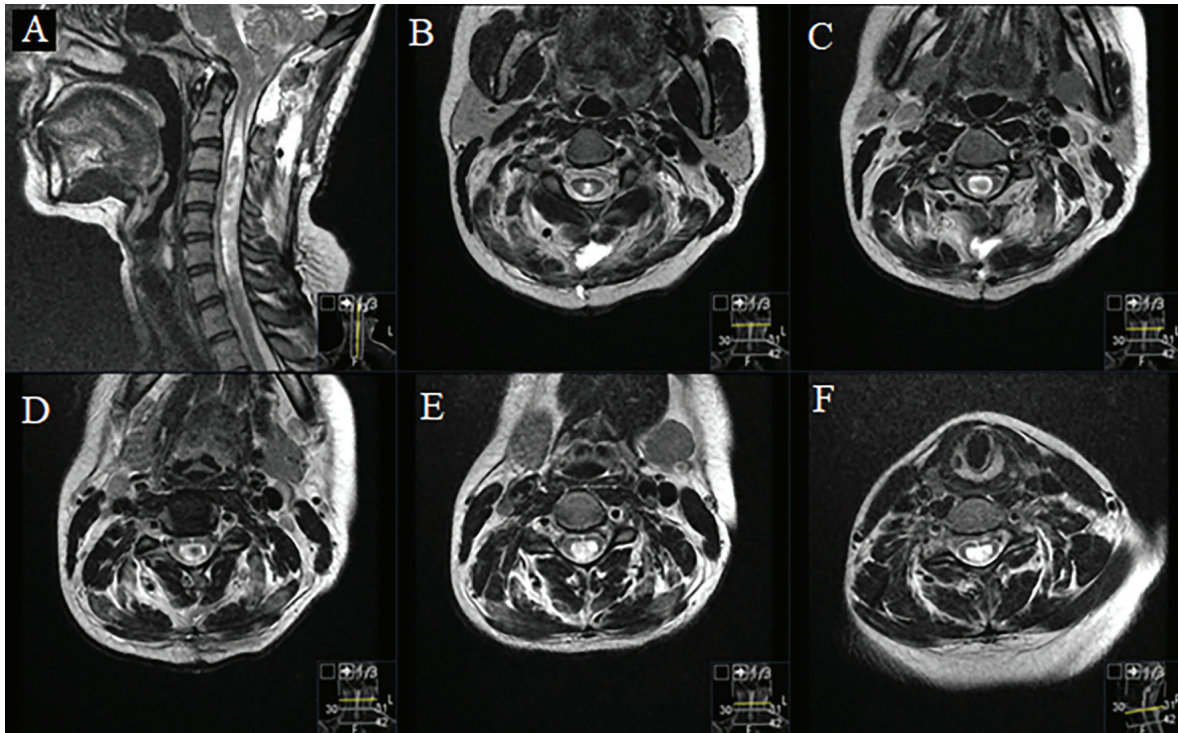


Figure 2: Early postoperative cervical MRI (postoperative day 2). Sagittal (A) and axial (B-F) T2-weighted images demonstrating adequate posterior fossa decompression following suboccipital craniectomy and C1 posterior arch excision.

MRI: Magnetic resonance imaging.

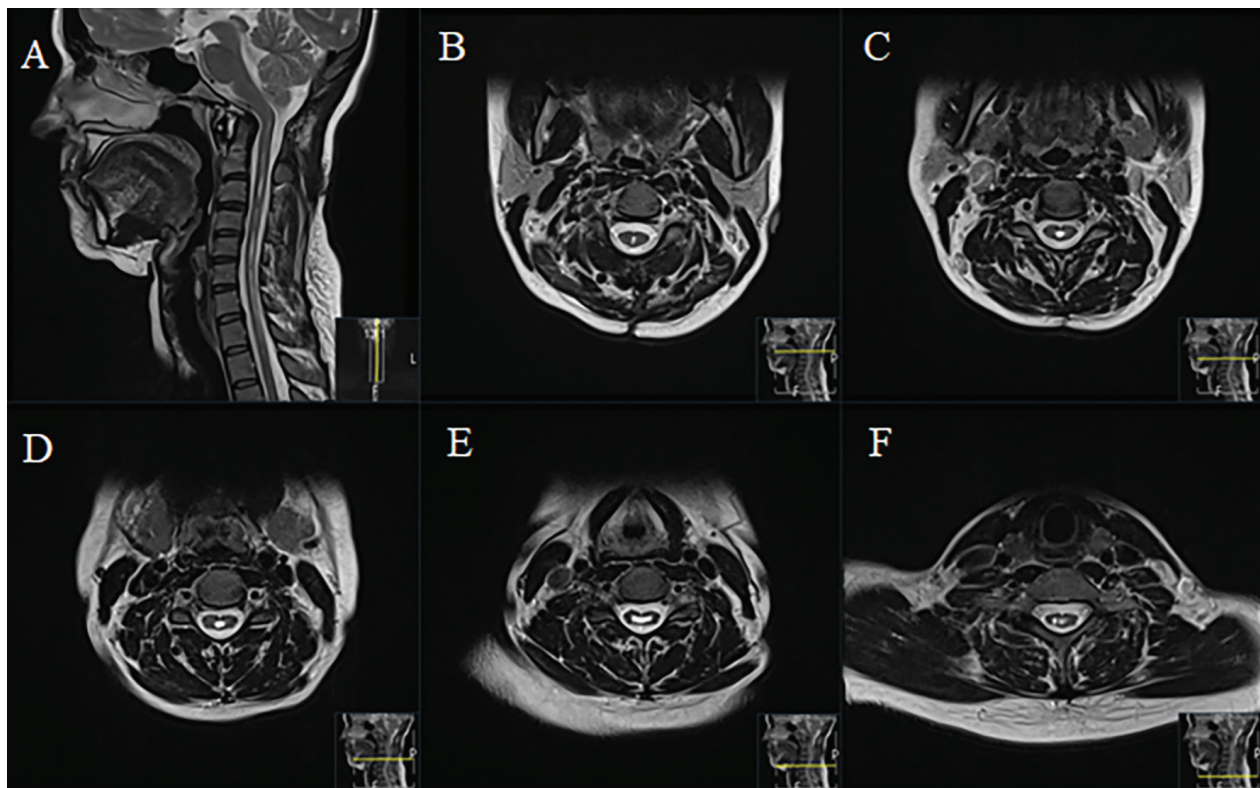


Figure 3: Six-month postoperative cervical MRI. Sagittal (A) and axial (B-F) T2-weighted images showing maintained posterior fossa decompression and interval reduction of the syrinx cavity.

MRI: Magnetic resonance imaging.

At the eighteen-month follow-up in March 2026, the patient remained clinically stable with no new neurological deficits. A repeat cervical MRI demonstrated sustained decompression at the craniocervical junction and interval reduction in the hydrosyringomyelia cavity (Figure 4). At the same reference levels, the syrinx measured 65 mm in length and 1.5×2 mm at C2. Because the follow-up examinations were not acquired with sequence parameters identical to those of the preoperative study, these values are presented as a comparison at matched anatomical levels rather than as an exact volumetric assessment. Clinically, the patient described her neck and left shoulder pain as substantially reduced and no longer limiting her daily activities, and she had returned to her usual occupational and domestic routine. No validated outcome instrument, such as a visual analogue scale or the Chicago Chiari Outcome Scale, was applied prospectively; therefore, the reported clinical improvement is descriptive.

DISCUSSION

The present case illustrates the diagnostic evaluation and surgical management of a 40-year-old female patient with CM-I associated with extensive cervicothoracic hydrosyringomyelia who was treated by posterior fossa decompression with duraplasty. Its instructive feature is the discrepancy between a tonsillar descent of only 4.5 mm and a syrinx spanning 130 mm of the cervicothoracic cord with associated cord

expansion and perisyrinx signal change. The case therefore argues against assessing Chiari-related pathology by a fixed numerical threshold of tonsillar herniation, and in favour of an individualised evaluation that integrates the clinical findings, posterior fossa crowding, craniocervical junction anatomy, syrinx burden, and the probable disturbance of CSF dynamics.

CM-I is characterised by the caudal displacement of the cerebellar tonsils through the foramen magnum, leading to crowding of the posterior fossa and disruption of normal CSF dynamics at the craniocervical junction (8). Obstruction of CSF flow at the level of the foramen magnum is considered the principal mechanism underlying the development of hydrosyringomyelia, which has been reported in 23-80% of patients with CM-I (4, 7, 8). Although the classical radiological threshold for the diagnosis of CM-I is ≥ 5 mm of tonsillar descent, Milhorat et al. (7) demonstrated in a cohort of 364 symptomatic patients that herniations as small as 3-5 mm may be clinically significant when accompanied by syringomyelia and other radiological features such as obliteration of the retrocerebellar CSF spaces and a steepened tentorial angle. Studies of posterior fossa morphology support this position. Sekula et al. (9) examined 22 patients who were symptomatic for CM-I but did not meet the accepted radiological criterion for tonsillar descent and found the dimensions of the posterior fossa to be reduced in this group, indicating that a crowded posterior fossa may be clinically relevant even when the descent falls below

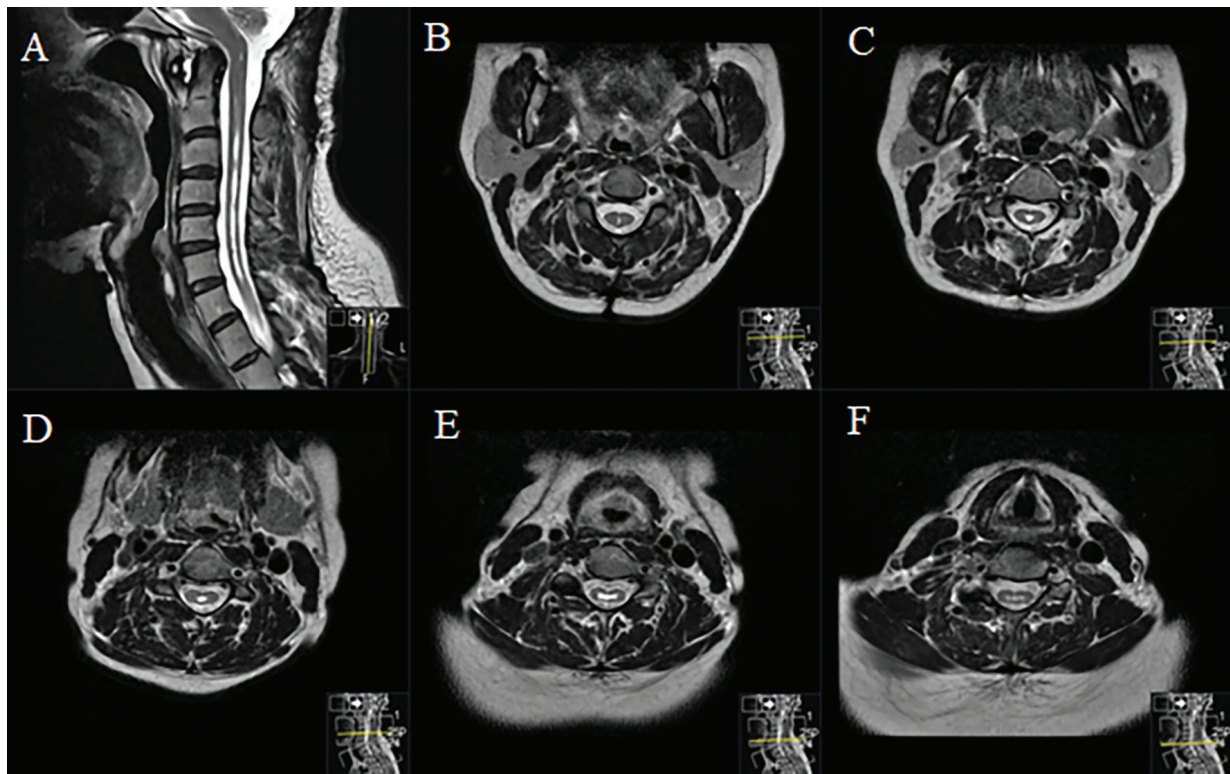


Figure 4: Eighteen-month postoperative cervical MRI. Sagittal (A) and axial (B-F) T2-weighted images demonstrating sustained posterior fossa decompression and reduction in the hydrosyringomyelia cavity compared to preoperative imaging.

MRI: Magnetic resonance imaging.

the conventional threshold. The disturbance of CSF flow and the overall craniocervical morphology therefore appear more clinically relevant than the absolute extent of tonsillar descent. In the present patient the descent was borderline at 4.5 mm, yet the subarachnoid spaces at C2 were effaced and the syrinx was extensive, indicating a functionally significant obstruction at the foramen magnum despite a sub-threshold measurement.

The clinical presentation of CM-I spans a broad spectrum, ranging from asymptomatic to severe neurological impairment (2, 6). The most frequently reported complaints are cervical pain and headache, and particularly suboccipital headache exacerbated by Valsalva manoeuvres. These are attributed to the stretching of pain-sensitive structures at the foramen magnum and to the elevated posterior fossa pressure (1, 2, 6). Less familiar presentations, including sleep-disordered breathing and orthostatic intolerance, are increasingly recognised but may be overlooked when the degree of tonsillar descent is borderline (10, 11). Our patient presented primarily with neck and left shoulder pain persisting for two months, consistent with the predominantly pain-related symptom profile described in the literature. The occasional stress urinary incontinence was considered nonspecific and could not be confidently attributed to the syrinx. In the absence of urological, gynaecological, or urodynamic assessment, neither a myelopathic origin nor pelvic floor dysfunction related to previous pregnancies can be established, and referral for formal evaluation would have been the appropriate course.

The development of a syrinx and the progression of neurological symptoms are widely regarded as indications for surgical intervention (1, 8, 12). In the present case the indication was not pain in isolation but the combination of an extensive syrinx, cord expansion and perisyrinx signal change, which together carried a risk of progressive and irreversible cord injury; this distinction is important because pain alone, in the absence of a syrinx or neurological deficit, would not ordinarily justify decompression. The objectives of surgery are to relieve compression at the craniocervical junction and to restore normal CSF circulation, with the aim of arresting or reversing syrinx progression (12, 13). Individualised selection of the extent of decompression according to the pattern of obstruction and the characteristics of the syrinx has been advocated, and dedicated scales have been proposed to grade syrinx resolution after surgery (13).

Posterior fossa decompression, which comprises suboccipital craniectomy, excision of the C1 posterior arch, and duraplasty, is the most commonly performed and widely accepted surgical procedure for CM-I (14, 15). Whether the dura should be opened remains debated. Bone-only decompression and dura-splitting techniques avoid entry into the subarachnoid space and are associated with shorter operative times, whereas duraplasty achieves a more reliable enlargement of the cisterna magna. A systematic review and meta-analysis found decompression with duraplasty and arachnoid preservation to be beneficial and to reduce the rate of reoperation, and comparative series have examined dura-splitting against combined techniques in

patients with syringomyelia (15, 16). Duraplasty was therefore preferred in this patient, in whom the syrinx was the dominant radiological abnormality. Regarding graft material, autologous fascia, aponeurosis or pericranium can be harvested from within the operative field, avoid the cost of a commercial product and are regarded by many surgeons as more physiological than synthetic substitutes; a synthetic graft was used in this case according to the operating surgeon's preference and the material available at the time of operation, and an autologous graft would have been an equally appropriate alternative. Our patient underwent a two-hour and 45-minute posterior fossa decompression. Blood loss was minimal. No intraoperative complications were encountered.

Following foramen magnum decompression, improvement in symptoms such as cervical pain, headache, and ataxia has been reported in the majority of patients. Klekamp reported that 73.6% of 371 patients demonstrated improvement at three months following decompression, whilst Alfieri and Pinna observed sustained clinical improvement in over 90% of their cohort with CM-I-related syringomyelia over a median follow-up of 12.7 years (17, 18). Han et al. (19) similarly documented clinical and radiological improvement one year after posterior fossa decompression in adults with CM-I and syringomyelia. However, established neurological deficits, such as motor weakness and sensory loss, are less likely to recover, underscoring the importance of timely intervention before irreversible spinal cord damage occurs (1, 3, 18). Despite a generally favourable safety profile, complications including CSF leakage, pseudomeningocele formation, wound infection, and, rarely, postoperative hydrocephalus have been reported in a proportion of patients (3, 15, 17, 20). In the present case the early postoperative course was uneventful, and the only adverse event during follow-up was a minor superficial wound problem at seven months that resolved with local care and topical antibiotic treatment. The patient described a substantial reduction in her neck and shoulder pain, the neurological examination remained unchanged throughout the 18-month follow-up period, and serial MRI demonstrated sustained decompression of the craniocervical junction with regression of the syrinx cavity, consistent with the favourable radiological outcomes reported in the literature (18, 19).

This case has certain limitations. First, as a single case report the findings are not generalisable. Second, the reported symptomatic improvement remains subjective. The clinical outcome was assessed descriptively: no validated instrument such as a visual analogue scale or the Chicago Chiari Outcome Scale was applied prospectively, and analgesic requirement and functional status were not recorded systematically. Third, the follow-up MRI studies were not acquired with sequence parameters identical to those of the preoperative examination, so the comparison of syrinx dimensions should be interpreted as an approximation at matched anatomical levels. Fourth, the urinary symptom was not evaluated by a urologist, a gynaecologist, or by urodynamic study, and its origin therefore remains undetermined. Finally,

the follow-up period, although 18 months, may not be sufficient to capture long-term complications or late recurrence, as neurological deterioration has been reported in up to 15% of patients within ten years of surgery (17). Continued clinical and radiological surveillance is therefore warranted.

CONCLUSION

This case suggests that posterior fossa decompression may provide clinical and radiological benefit in selected patients with extensive syringomyelia and borderline tonsillar descent when the overall findings are suggestive of impaired CSF dynamics at the craniocervical junction. It also illustrates that the clinical significance of Chiari-related pathology cannot be determined by the millimetric extent of tonsillar descent alone, and that the decision to operate should follow an individualised assessment of craniocervical anatomy, syrinx burden, and CSF flow rather than a single radiological cut-off. Larger series with longer follow-up and standardised outcome measures are needed to define which patients with borderline herniation derive the greatest benefit from decompression.

Ethics

Informed Consent: Written and verbal informed consent was obtained from the patient for this article.

Footnotes

Conflict of Interest: The authors declared no conflict of interest.

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DEGENERATIVE CERVICAL MYELOPATHY IN A PATIENT WITH KLIPPEL-FEIL SYNDROME ACCOMPANIED BY CONGENITAL ANOMALIES OF THE PEDICLE AND LATERAL MASS: A CASE REPORT

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ABSTRACT

Klippel-Feil syndrome is a rare congenital cervical fusion anomaly that may lead to degenerative changes and neurological symptoms later in life. Degenerative cervical myelopathy is progressive, and surgical treatment is recommended in moderate and severe cases. A 53-year-old man presented with progressive weakness, spastic gait, and neuropathic complaints. Neurological examination revealed spastic quadriparesis with hyperreflexia, ankle clonus, and bilateral Hoffmann sign positivity. The preoperative modified Japanese Orthopaedic Association score was 11, and the Nurick grade was three. Imaging demonstrated congenital C2-C3 fusion consistent with Klippel-Feil syndrome type II, multilevel cervical canal stenosis, and hypoplasia of the right C5 pedicle and lateral mass. C3-C4-C5 laminectomy was performed for decompression, and lateral mass screw and rod instrumentation was applied over C3-C6. Because the right C5 lateral mass was hypoplastic, no screw was placed at that site; the right-sided construct spanned C3, C4, and C6, and C5 was anchored on the left only. At 18 months the modified Japanese Orthopaedic Association score had improved to 16 and the Nurick grade to one, with no implant-related complications. Degenerative cervical myelopathy arising on a background of Klippel-Feil syndrome may require individualized surgical planning, because coexisting congenital anomalies can determine which fixation points are usable. Careful preoperative radiological assessment and posterior decompression with stabilization can provide satisfactory clinical outcomes.

Keywords: Klippel-Feil syndrome, spinal cord compression, spinal cord diseases, spinal stenosis, vertebral cervical fusion syndrome

INTRODUCTION

Klippel-Feil syndrome (KFS) is a rare spinal anomaly characterized by congenital fusion of the cervical vertebrae, which can present with neurological symptoms in adulthood in some patients. Congenital cervical fusion has been reported to be associated with increased mechanical stress and degenerative changes in adjacent segments. Degenerative cervical myelopathy (DCM) is one of the most common causes of non-traumatic spinal cord dysfunction in adults, and its progressive course calls for early diagnosis and appropriate surgical treatment (1, 2).

The clinical severity of DCM is commonly assessed using the modified Japanese Orthopaedic Association (mJOA) score and the Nurick grade. According to the mJOA classification, DCM

severity is categorized as mild (mJOA 15 or above), moderate (mJOA 12 to 14), or severe (mJOA below 12) (1). Preoperative Magnetic resonance imaging (MRI) parameters, particularly T2 intramedullary signal change, provide additional prognostic information about the outcome of surgery in patients with DCM (3).

Current clinical practice guidelines strongly recommend surgical treatment in patients with moderate and severe myelopathy (1). When multilevel decompression is required in the subaxial cervical spine, lateral mass screw fixation is the most widely used posterior fixation technique, as it provides immediate stabilization and reduces the risk of post-laminectomy kyphosis (4).



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Surgical planning may be more demanding in patients with KFS, because congenital anomalies of the pedicle and lateral mass can occur alongside the fusion and become relevant once posterior instrumentation is considered. Congenital pedicle anomalies of the cervical spine include hypoplasia, aplasia, and dysplasia and may be accompanied by an abnormal vertebral artery course. Their prevalence in the general population remains unclear, but they have been documented in computed tomography (CT)-based morphometric studies and may influence screw trajectory planning (4). Lateral mass anomalies, such as hypoplasia or asymmetry, can further complicate fixation strategies. Both therefore call for detailed preoperative CT evaluation and careful selection of screw technique and fixation points before implants are placed (5, 6).

In this case report, we present the individualized surgical approach, the management process, and the clinical and radiological outcomes after posterior decompression and stabilization in a patient with DCM that developed on a background of KFS type II, with congenital anomalies of the C5 pedicle and lateral mass.

CASE REPORT

A 53-year-old man presented to our clinic with left-sided weakness and arm pain that had persisted for approximately eight years and had worsened in recent months. He had a 45 pack-year cigarette smoking history.

Physical examination revealed upper motor neuron findings: bilateral Hoffmann sign positivity, hyperactive deep tendon reflexes (+++/+++), ankle clonus, and increased muscle tone. Motor examination demonstrated asymmetric spastic quadriparesis, with strength graded 4+/5 on the right and 4/5 on the left in both the upper and lower extremities. The patient described dysesthetic complaints in the left hand and the medial aspect of the left leg. His gait was spastic, characterized by increased tone in the lower extremity extensor muscle groups (quadriceps and gastrocnemius-soleus complex), a stiff-legged pattern, reduced stride length, and circumduction, with scissoring observed during ambulation. The velocity-dependent hypertonicity on passive stretch, the ankle clonus, and this gait pattern together established the spasticity as being of upper motor neuron origin.

Preoperative neurological assessment showed an mJOA score of 11 and a Nurick grade of three. Functionally, the patient was able to button a shirt only with great difficulty, could manage stairs only with the aid of a handrail, had mild sensory loss in the hands, and reported mild to moderate difficulty with micturition. He remained independently ambulant but was unable to work at full capacity.

Plain radiographs of the cervical spine, including flexion, neutral, and extension lateral views, demonstrated congenital fusion of the C2 and C3 vertebral bodies with loss of the intervening disc space, consistent with KFS type II (Figure 1). Magnetic resonance

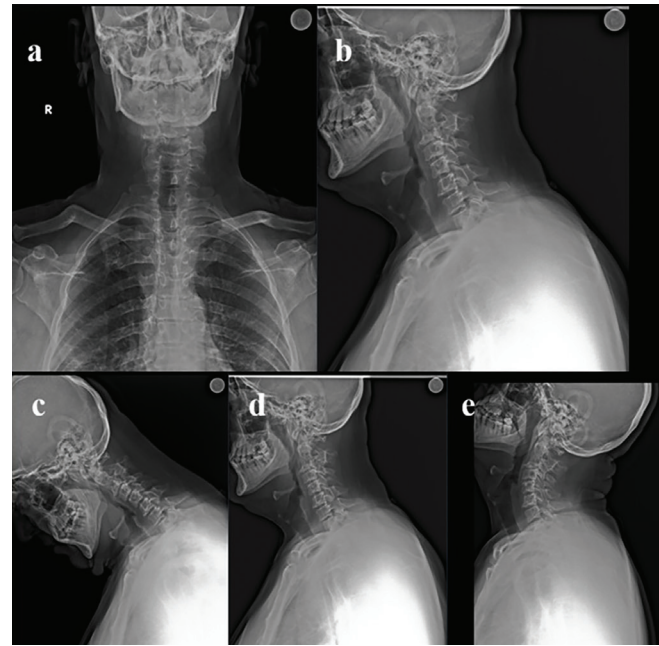


Figure 1: Preoperative plain radiographs of the cervical spine: (a) anteroposterior and (b) lateral views, and (c) flexion, (d) neutral, and (e) extension lateral views. The images reveal congenital fusion of the C2 and C3 vertebral bodies with loss of the intervening disc space, consistent with Klippel-Feil syndrome type II.

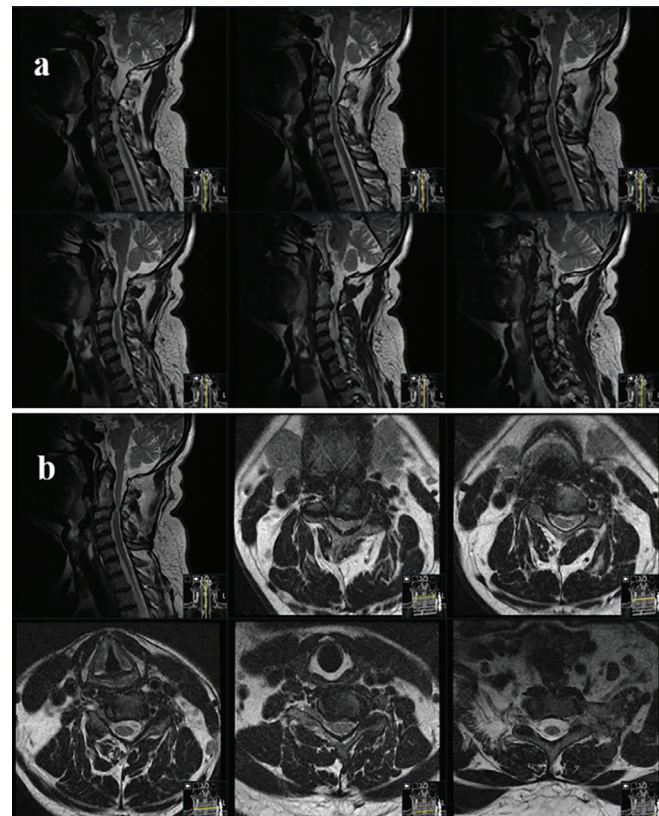


Figure 2: Preoperative T2-weighted MRI of the cervical spine: (a) sagittal images and (b) sagittal and axial images at the stenotic levels. The images reveal multilevel cervical canal stenosis with spinal cord compression, most prominent at the C3-C4 intervertebral disc level. Intramedullary T2 hyperintense signal change is present within the spinal cord at the level of maximum compression, suggesting myelopathic change. MRI: Magnetic resonance imaging.

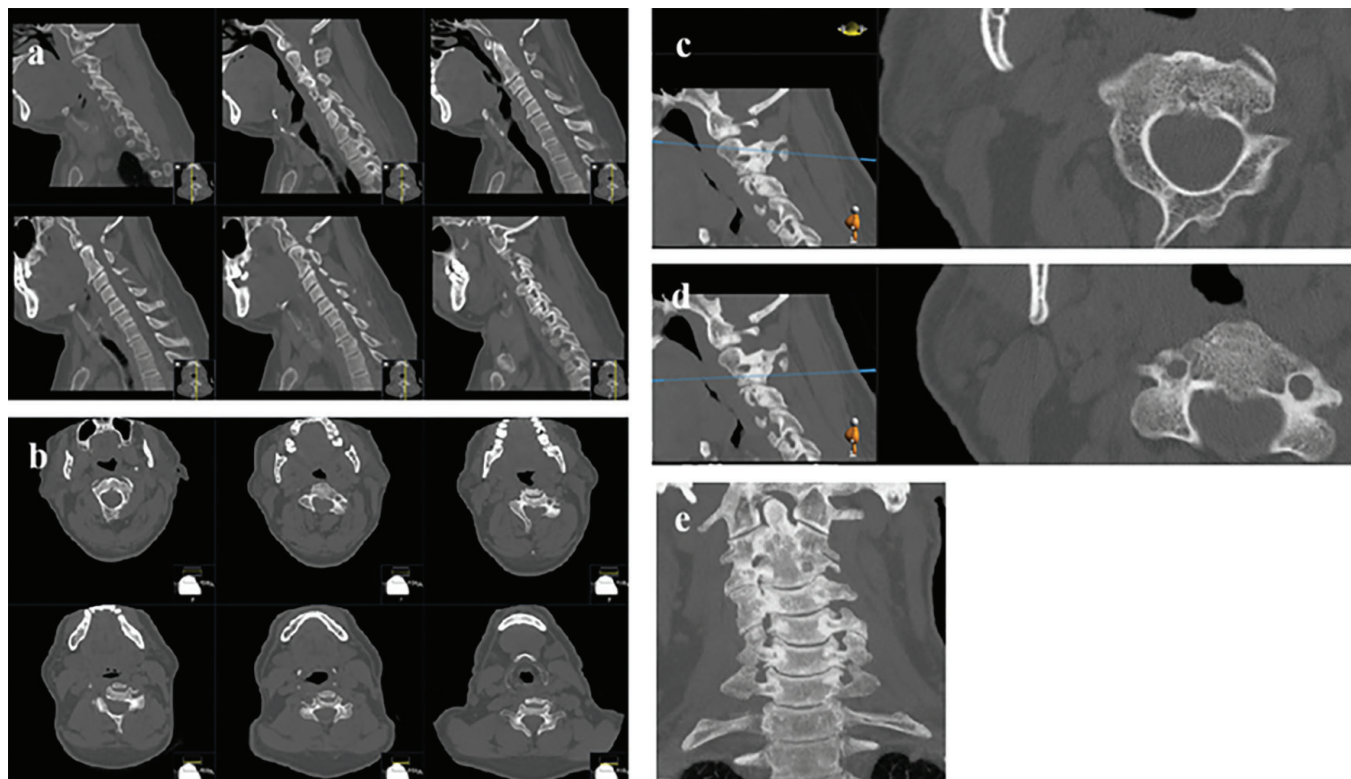


Figure 3: Preoperative CT images of the cervical spine: (a) sagittal reconstructions demonstrating congenital C2-C3 vertebral fusion with absence of the intervertebral disc and a continuous bony bridge, consistent with Klippel-Feil syndrome type II; (b) axial image at the C5 level revealing hypoplasia of the right pedicle and lateral mass; (c, d) axial images at the C3 and C4 pedicle levels, shown for comparison with the adjacent normal anatomy; (e) coronal reconstruction confirming the asymmetry of the right C5 lateral mass and pedicle compared with the left side. CT: Computed tomography.

cord compression, most prominent at the C3-C4 level, together with intramedullary T2 hyperintense signal change at the level of maximum compression (Figure 2). CT confirmed the continuous C2-C3 bony bridge and demonstrated hypoplasia of the right C5 pedicle and lateral mass, with clear asymmetry relative to the left side (Figure 3).

The patient's symptoms were predominantly left-sided, whereas the congenital bony anomaly was on the right. The two findings are not related. The clinical picture reflects the distribution of spinal cord compression rather than the side of the pedicle and lateral mass hypoplasia, which has no direct neural consequence in this patient and is relevant only to instrumentation.

Based on the clinical severity and the multilevel radiological findings, a single-stage posterior decompression and stabilization procedure was planned. The strategy comprised C3-C4-C5 laminectomy for spinal cord decompression and lateral mass screw fixation with rod instrumentation over the C3-C6 levels for stabilization.

Preoperative CT governed how that construct was built. The right C5 lateral mass and pedicle were hypoplastic to a degree that would not have provided adequate bone for safe screw purchase, and the reported association between congenital cervical pedicle anomalies and an anomalous vertebral artery course reinforced the decision not to instrument that site (5).

Screw placement at the right C5 was therefore abandoned at the planning stage rather than attempted and revised during surgery.

Using a posterior approach, C3-C4-C5 laminectomy and spinal cord decompression were performed. Lateral mass screws were then placed bilaterally at C3, C4, and C6, and on the left side only at C5, giving a seven-screw construct. The right-sided rod therefore spanned C3, C4, and C6, bridging the anomalous C5 level without an anchor, while the left-sided rod engaged all four levels. Extending the instrumentation caudally to C6, one level below the most caudal laminectomy, was a deliberate consequence of this asymmetry: it restored a bilateral distal anchor below the skipped level and prevented the right-sided construct from terminating on a single fixation point.

To promote posterolateral arthrodesis, the lateral masses and facet joints at each instrumented level were thoroughly decorticated using a high-speed burr, and locally harvested autogenous bone graft obtained from the laminectomy was applied over the decorticated surfaces (Figures 4, 5). There were no complications during surgery, and the early postoperative period was uneventful.

At the 18-month follow-up, marked neurological improvement was observed. Spasticity and motor weakness had regressed. The mJOA score improved to 16 and the Nurick grade to one.

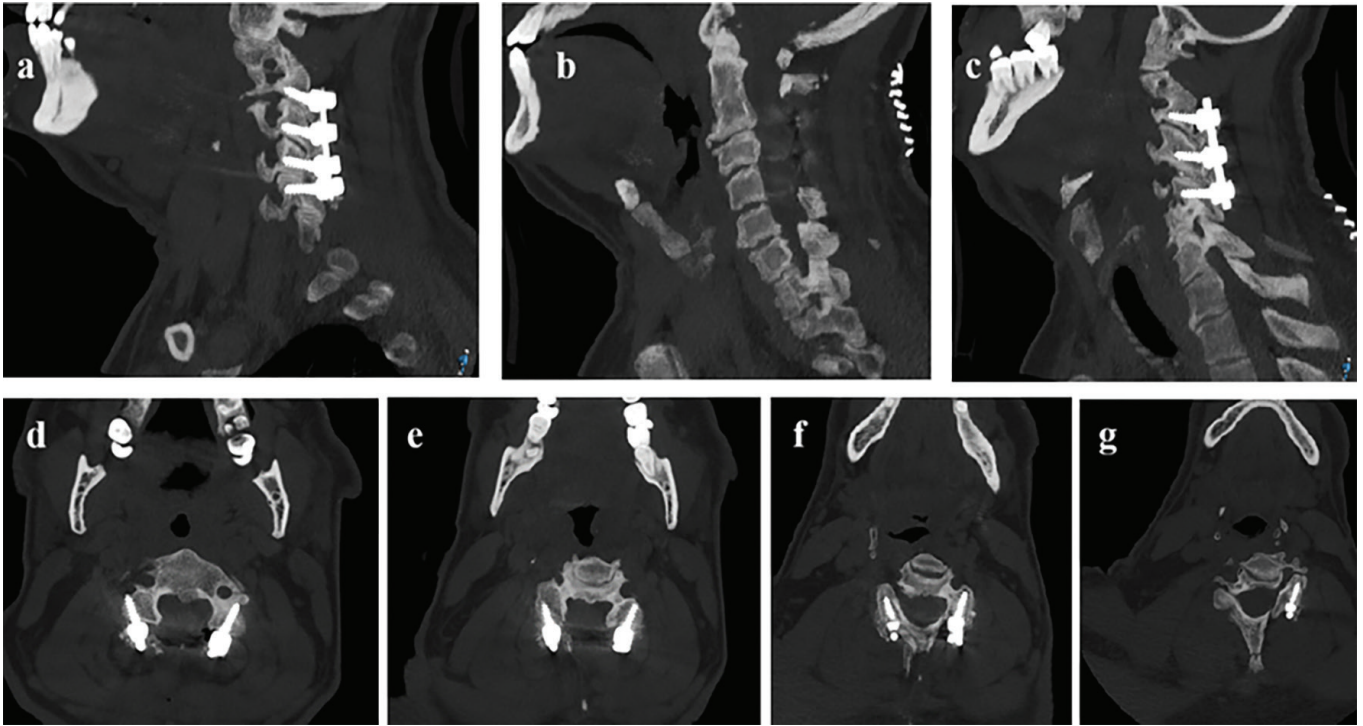


Figure 4: Early postoperative CT images of the cervical spine: (a, b, c) sagittal and (d, e, f, g) axial images. The images demonstrate satisfactory positioning of the lateral mass screws, placed bilaterally at C3, C4, and C6 and on the left side at C5, with the connecting rods in place. No screw was placed in the hypoplastic right C5 lateral mass. Adequate decompression following C3-C5 laminectomy is confirmed, with widening of the spinal canal and no evidence of hardware malposition or canal compromise.

CT: Computed tomography.

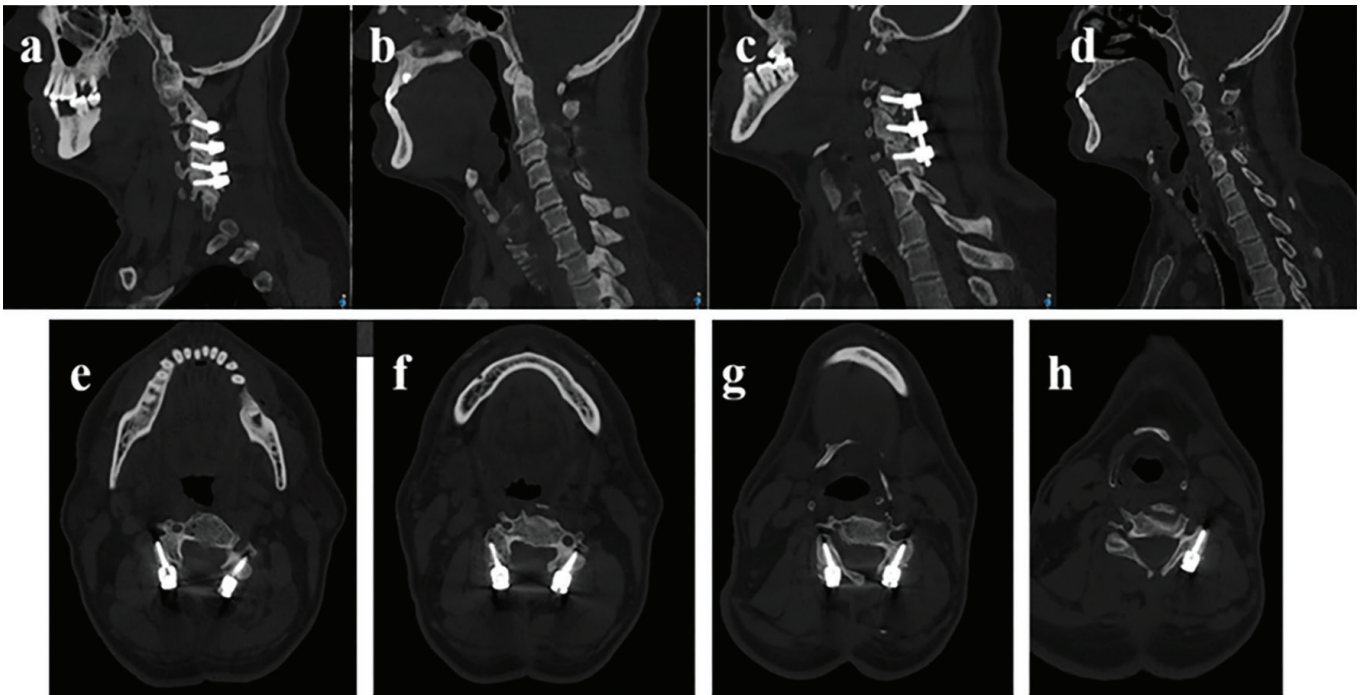


Figure 5: Six-month postoperative CT images of the cervical spine: (a, b, c, d) sagittal and (e, f, g, h) axial images. Compared with the early postoperative study, cervical alignment is maintained and hardware position is stable, with no evidence of screw loosening or rod displacement. The axial images confirm persistent canal decompression at the laminectomy levels. Early signs of posterolateral bony fusion are observed at the instrumented segments.

CT: Computed tomography.

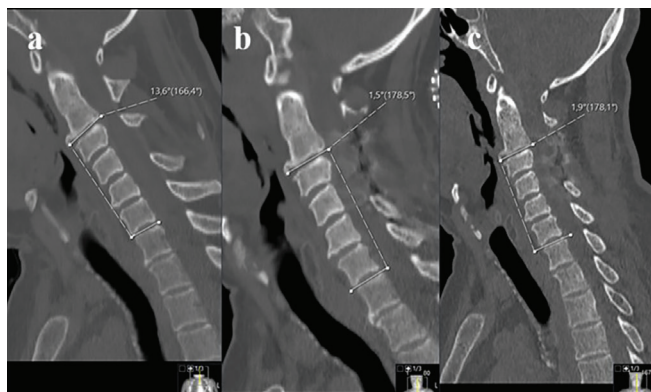


Figure 6: Cervical lordosis angles measured using the C3-C7 Cobb method on sagittal CT images at three time points: (a) preoperative, 13.6 degrees; (b) early postoperative, 1.5 degrees; and (c) six months postoperatively, 1.9 degrees. Lordosis decreased following decompression and instrumentation but showed no further decline between the early postoperative and six-month studies, and the instrumented segment did not progress to kyphosis. Because these angles were measured on supine CT rather than on standing lateral radiographs, they should be interpreted as a within-modality comparison.

CT: Computed tomography

The patient was able to button a shirt with only slight difficulty, walked unaided with a mild lack of stability, had no residual sensory loss in the hands, and reported normal micturition.

Imaging follow-up used two modalities at different time points. CT was obtained in the early postoperative period and at six months to assess implant position, canal decompression, and progression of fusion (Figures 4-6). MRI was obtained at 18 months and confirmed sustained decompression with partial resolution of the intramedullary T2 signal change (Figure 7). No implant-related complication was observed at any point during the 18-month period.

DISCUSSION

Neurological symptoms in patients with KFS may appear in adulthood and may be associated with degenerative changes developing in adjacent segments rather than at the fused level (7, 8). Nouri et al. (9) demonstrated, in a large multicenter cohort of patients with

DCM, that those with congenital cervical fusion exhibited degenerative changes preferentially affecting the segments adjacent to the fused levels, particularly at midcervical levels, supporting the role of adjacent segment pathomechanics in symptomatic KFS patients. Samartzis et al. (7) further characterized congenital fusion patterns in KFS, noting that Type II fusion patterns also carry a risk for developing clinically significant radiculopathic or myelopathic symptoms. Despite

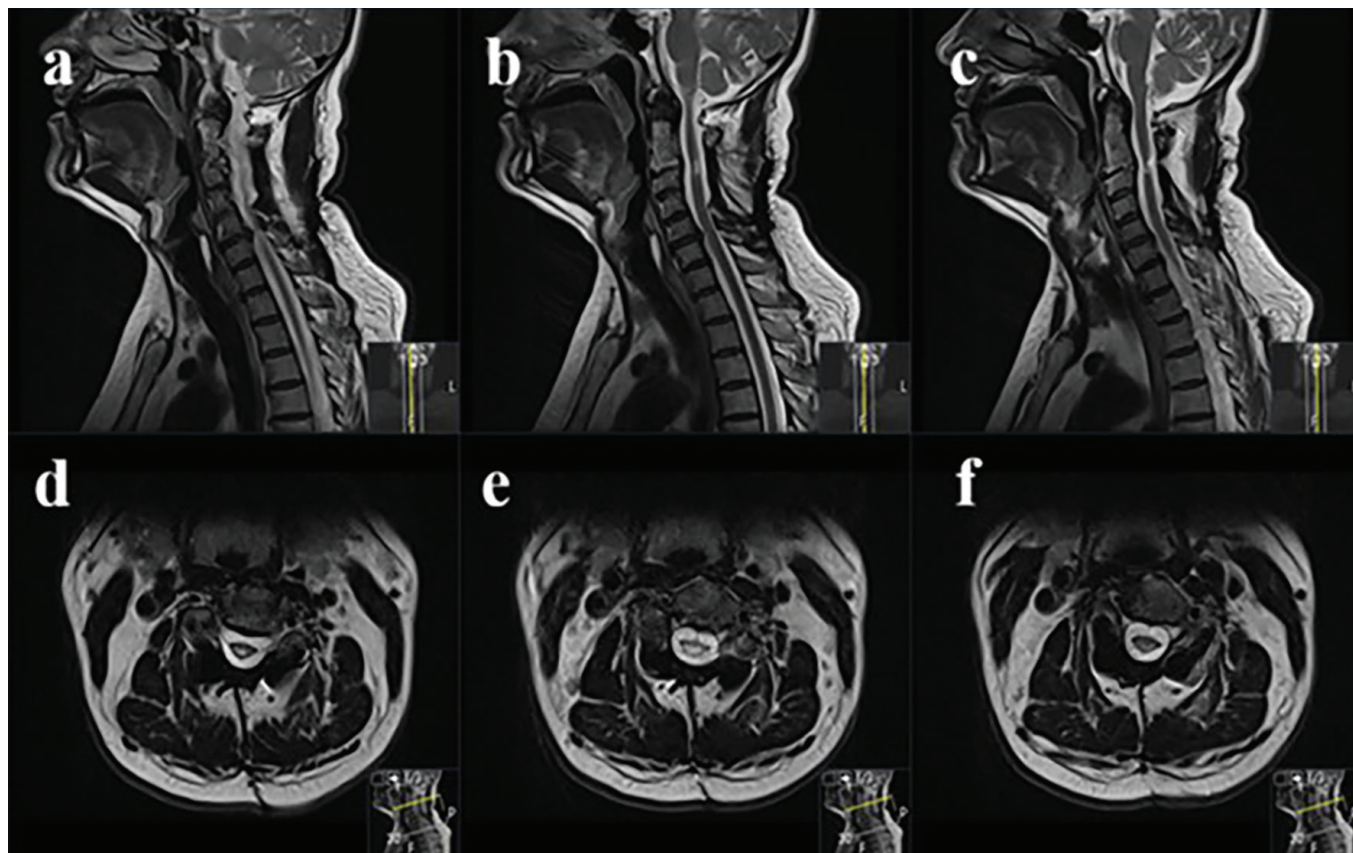


Figure 7: Eighteen-month postoperative T2-weighted MRI of the cervical spine: (a, b, c) sagittal and (d, e, f) axial images. The images reveal adequate spinal cord decompression with partial resolution of the previously observed T2 hyperintense signal change, suggesting recovery from myelopathic change. The sagittal images demonstrate maintained cervical alignment with no evidence of recurrent cord compression at the decompressed levels and no new major degenerative pathology at the adjacent segments.

MRI: Magnetic resonance imaging.

congenital fusion at C2-C3, spinal cord compression was maximal at C3-C4, the segment immediately caudal to the fusion, and extended across the subaxial levels below it.

Degenerative cervical myelopathy is a progressive disorder, and delayed treatment may lead to neurological deterioration. Current clinical practice guidelines strongly recommend surgical treatment in moderate and severe DCM (1). With a preoperative mJOA score of 11 and a Nurick grade of three, our patient fell clearly within that indication. The improvement to an mJOA score of 16 and a Nurick grade of one at 18 months objectively demonstrates the functional effectiveness of surgical treatment.

The technical difficulty in this case lay in the fixation rather than the decompression. Congenital anomalies of the pedicle and lateral mass are among the recognized challenges of posterior instrumentation in KFS, and they may render an intended fixation point unusable (5, 6, 10). Here the hypoplastic right C5 lateral mass was identified on preoperative CT, and the construct was designed around it. Three decisions followed from that single finding: the right C5 screw was omitted, C5 was anchored on the left side alone, and the instrumentation was extended caudally to C6, one level below the most caudal laminectomy, so that the right-sided rod regained a distal anchor and did not terminate on a solitary fixation point.

An asymmetric construct of this kind involves a trade-off. It reduces the number of fixation points on one side and is theoretically less rigid than a symmetric multilevel construct. We considered that trade-off preferable to placing a screw in bone unable to hold it, particularly given the reported association between congenital cervical pedicle anomalies and an anomalous vertebral artery course (5). The six-month CT showed stable hardware position without screw loosening or rod displacement, together with early posterolateral fusion at the instrumented segments, which suggests that the construct was adequate for this patient. In KFS, the preoperative CT therefore carries a second purpose beyond documenting the fusion, which is to establish which fixation points are usable.

The development of adjacent segment degeneration and instability in KFS remains controversial. Some early reports have suggested increased adjacent segment pathology in KFS patients (11), whereas more recent studies, including a large multicenter analysis by Nouri et al. (9), have demonstrated that congenital cervical fusion is associated with a higher prevalence of degenerative changes preferentially affecting midcervical levels, yet the risk of symptomatic adjacent segment disease is not uniformly elevated. Surgical decisions should therefore be individually tailored based on clinical findings and radiological evaluation. In this case, posterior decompression and stabilization were preferred due to multilevel canal stenosis and significant myelopathy.

Instrumentation accompanying posterior laminectomy has been shown to contribute to the maintenance of cervical stability and the prevention of post-laminectomy kyphosis, particularly in the presence of congenital anomalies. Kyphotic deformity is a well-documented consequence of multilevel cervical laminectomy

performed without supplementary fixation, and the addition of posterior instrumentation is therefore considered beneficial when multilevel decompression is performed, particularly in the presence of pre-existing instability (12-15). In the present case, cervical lordosis measured by the C3-C7 Cobb method decreased from 13.6 degrees preoperatively to 1.5 degrees in the early postoperative period. It showed no further decline by six months (1.9 degrees), and the instrumented segment did not progress to kyphosis. We therefore interpret the construct as having arrested, rather than prevented, the loss of lordosis that accompanied the decompression. No implant-related complications were observed during the 18-month follow-up period.

This report has several limitations. Sagittal alignment was assessed on supine CT rather than on standing lateral radiographs, which are the appropriate modality for measuring cervical Cobb angles. Postoperative standing radiographs were not available for this patient, so the reported angles should be read as a within-modality comparison and may not reflect standing alignment. The radiological follow-up is also uneven: CT extends to six months and MRI to 18 months, so the alignment data end at six months while the clinical and MRI follow-up extends to 18 months. Finally, the study is a single case, and the construct described here should not be generalized without further reports.

In summary, DCM developing on a background of KFS can be treated effectively by posterior decompression and instrumented stabilization. Coexisting congenital anomalies may determine which fixation points are available and should be identified on preoperative CT.

Ethics

Informed Consent: Written informed consent was obtained from the patient for this study.

Footnotes

Conflict of Interest: The authors declared no conflict of interest.

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