



A Case Report on the Progression of Ambulation in a Child with T12 AIS C Spinal Cord Injury

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Introduction

- This case report describes the progression of ambulation in a child with **T12 AIS C** spinal cord injury from 3 to 9 years of age.
- The child progressed from ambulating with a swing-to gait pattern using a locked hip-knee-ankle-foot orthosis (HKAFO) to ambulating with a reciprocal gait pattern using a stance-control reciprocating gait orthosis (SC-RGO).
- This case highlights the clinical decision-making process that allowed for this progression, taking into account the child's age, level of maturity, and partial recovery of motor function over time.



Patient Background

- **3-year-old** male initially followed for acute IP rehab
- MOI: GSW to the abdomen
- Diagnosis on admission: **T10 complete SCI**
- Presented with **flaccid paralysis** of the bilateral lower extremities



Clinical Findings – Age 3

Right Lower Extremity	Left Lower Extremity
Hip flexion 0/5	Hip flexion 0/5
Hip adduction 0/5	Hip adduction 0/5
Hip abduction 0/5	Hip abduction 0/5
Hip extension 0/5	Hip extension 0/5
Knee extension 0/5	Knee extension 0/5
Knee flexion 0/5	Knee flexion 0/5
Ankle DF/PF 0/5	Ankle DF/PF 0/5


Age 3

Therapeutic Intervention

- **Acute IP Rehab** x 4 weeks
- **Outpatient PT** 3-6x per month x 4 months
- Sitting balance
- Floor mobility
- Static standing
- Gait training (GT)

Progression of Ambulation

- Upright mobility was initiated with TLSO, AFOs and knee immobilizers
- HKAFO 3 mos. post-injury
- Anterior RW
- Swing-to gait pattern
- 500 ft with CG/close S



HKAFO with Drop Locks at Hips and Knees





Evidence for Upright Mobility

- Standing and upright mobility offer psychological benefits to the child with SCI (2)
- HKAFOs are commonly used for children with thoracic level injuries with weak/absent hip and knee extensors (1)
- Standing for at least one hour 5 days per week may help to prevent loss of bone mineral density in patients with acute SCI if begun within 8-12 weeks of injury (3, 4)

Swing-to Gait with HKAFOs – Age 4





Clinical Findings – Age 4

Right Lower Extremity	Left Lower Extremity
Hip flexion 1+/5	Hip flexion 2+/5
Hip adduction 0/5	Hip adduction 0/5
Hip abduction 0/5	Hip abduction 0/5
Hip extension 0/5	Hip extension 0/5
Knee extension 1/5	Knee extension 2+5
Knee flexion 1/5 *medial hamstrings only	Knee flexion 2+/5 *medial hamstrings only
Ankle DF/PF 0/5	Ankle DF/PF 0/5

Age 4-5

Therapeutic Intervention

- **OP PT** 2-4x per month
- Gait training
- Body weight supported GT
 - 27 sessions over 15 months
 - Treadmill and over-ground
 - With AFOs donned
- HF stretching
- LE adaptive tricycle

Progression of Ambulation

- Locked HKAFO
 - Hip flexion contractures prevented reciprocal gait despite strong hip flexors
- Anterior RW
- Introduced forearm crutches
- Swing-to gait pattern
- CGA



Clinical Findings – Age 5 Modified ISNCSCI Examination



INTERNATIONAL STANDARDS FOR NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY (ISNCSCI)



Patient Name _____ Date/Time of Exam _____
Examiner Name _____ Signature _____

RIGHT

MOTOR KEY MUSCLES

SENSORY KEY SENSORY POINTS Light Touch (LT) Pin Prick (PP)

	C2	2	2
	C3	2	2
	C4	2	2
UER (Upper Extremity Right)	Elbow flexors C5	5	2
	Wrist extensors C6	5	2
	Elbow extensors C7	5	2
	Finger flexors C8	5	2
	Finger abductors (little finger) T1	5	2
Comments (Non-key Muscle? Reason for NT? Pain?): Bilateral Non-Key Muscles: Hip adduction, hip extension	T2	2	2
	T3	2	2
	T4	2	2
	T5	2	2
	T6	2	2
	T7	2	2
	T8	2	2
	T9	2	2
	T10	2	2
	T11	2	2
	T12	2	2
	L1	2	0
LER (Lower Extremity Right)	Hip flexors L2	4	0
	Knee extensors L3	1	0
	Ankle dorsiflexors L4	0	0
	Long toe extensors L5	0	0
	Ankle plantar flexors S1	0	0
	S2	0	0
	S3	0	0
	S4-5	0	0
(VAC) Voluntary anal contraction (Yes/No)	NT		

RIGHT TOTALS (MAXIMUM)	30	40	38
	(50)	(56)	(56)

MOTOR SUBSCORES

UER [25] + UEL [25] = UEMS TOTAL [50] LER [5] + LEL [7] = LEMS TOTAL [12]
MAX (25) (25) (50) MAX (25) (25) (50)

NEUROLOGICAL LEVELS
Steps 1-5 for classification as on reverse

1. SENSORY	R [T12]	L [T12]
2. MOTOR	R [T12]	L [T12]

3. NEUROLOGICAL LEVEL OF INJURY (NLI) [T12]

4. COMPLETE OR INCOMPLETE? [UTD]
Incomplete = Any sensory or motor function in S4-5

5. ASIA IMPAIRMENT SCALE (AIS) [UTD]

(In complete injuries only)
ZONE OF PARTIAL PRESERVATION
Most caudal level with any innervation

SENSORY	R [UTD]	L [UTD]
MOTOR	R [UTD]	L [UTD]

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LEFT

MOTOR KEY MUSCLES

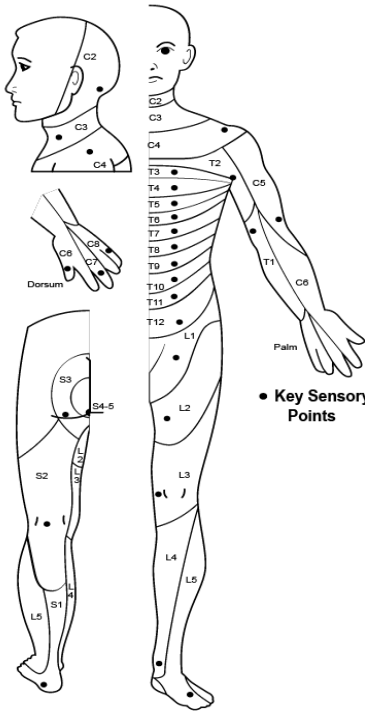
SENSORY KEY SENSORY POINTS Light Touch (LT) Pin Prick (PP)

	C2	2	2
	C3	2	2
	C4	2	2
UEL (Upper Extremity Left)	C5	5	2
	C6	5	2
	C7	5	2
	C8	5	2
	T1	5	2
MOTOR (SCORING ON REVERSE SIDE)	T2	2	2
	T3	2	2
	T4	2	2
	T5	2	2
	T6	2	2
	T7	2	2
	T8	2	2
	T9	2	2
	T10	2	2
	T11	2	2
	T12	2	2
	L1	0	0
SENSORY (SCORING ON REVERSE SIDE)	L2	5	2
	L3	2	0
	L4	0	0
	L5	0	0
	S1	0	0
	S2	0	0
	S3	0	0
	S4-5	0	0
(VAC) Voluntary anal contraction (Yes/No)	NT		

LEFT TOTALS (MAXIMUM)	32	38	38
	(50)	(56)	(56)

SENSORY SUBSCORES

LTR [40] + LTL [38] = LT TOTAL [78] PPR [38] + PPL [38] = PP TOTAL [76]
MAX (56) (56) (112) MAX (56) (56) (112)



0 = total paralysis
1 = palpable or visible contraction
2 = active movement, gravity eliminated
3 = active movement, against gravity
4 = active movement, against some resistance
5 = active movement, against full resistance
5+ = normal corrected for pain/disuse
NT = not testable

0 = absent
1 = altered
2 = normal
NT = not testable

NT (DAP) Deep anal pressure (Yes/No)



Clinical Findings – Age 5

Modified ISNCSCI Examination

Right Lower Extremity		Left Lower Extremity	
L2	4/5	L2	5/5
L3	1/5	L3	2/5
L4	0/5	L4	0/5
L5	0/5	L5	0/5
S1	0/5	S1	0/5



Complication – Age 5 ½

- **Hip flexion contractures 80 degrees bilaterally**
 - Prevented use of strong hip flexors for reciprocal gait pattern
- **Surgery:**
 - **RLE:** Release of IT band, TFL, and Sartorius
 - **LLE:** Release of TFL and Sartorius
- Hip flexion contractures 5 degrees bilaterally post-operatively



Evidence for Reciprocal Gait

- Reduces the metabolic cost of ambulation in children with T and L level spinal lesions (5)
 - With locked HKAFO → up to 6x more than that of typically developing peers
 - With reciprocating gait orthosis (RGO) → only 2x more
- Less strain on upper extremities than swing-to gait pattern

Options Considered for Reciprocal Gait

1. Unlocked HKAFO

2. Isocentric RGO

- Allows reciprocal gait pattern with THKAFO
- As one hip flexes the other hip extends via a pelvic band with a central pivot point
- Knee joints are locked in extension → results in compensatory movements (vaulting, circumduction) (6)



Options Considered for Reciprocal Gait

3. SC-HKAFO

- Unlocked HKAFO with SC knee joints
- Pelvic band for M-L stability
- Knee stability in stance
- Free knee flexion in swing

Stance Control KAFO:

- Reduces energy consumption
- Improves gait kinematics (7,8)



Options Considered for Reciprocal Gait

4. SC-RGO

- Isocentric RGO with stance-control knee joint in place of typical drop-lock knee joint
- Shown to improve gait efficiency (speed, stride length) in an adult with T10 complete SCI vs. traditional RGO (6)





Clinical Findings – Age 6

Right Lower Extremity	Left Lower Extremity
Hip flexion 4/5	Hip flexion 4/5
Hip adduction 2/5	Hip adduction 2/5
Hip abduction NT	Hip abduction NT
Hip extension 1/5	Hip extension 1/5
Knee extension 1+/5	Knee extension 3/5
Knee flexion 3/5	Knee flexion 3/5
Ankle DF/PF 0/5	Ankle DF/PF 0/5

Age 6

Therapeutic Intervention

- **OP PT** 1x/week
- Gait training
 - SC-HKAFO (unlocked hips)
 - SC-RGO
 - **Reciprocal gait pattern**
S/P surgical release of hip flexors
- HF stretching

Progression of Ambulation

- **SC-HKAFO**
 - Anterior RW
 - Despite surgical release of hip flexors, child still unable to maintain hip extension due to hip extensor weakness
- **SC-RGO**
 - Provided A-P hip stability (maintaining extension in stance)
 - Anterior RW

Reciprocal gait with SC-RGO – Age 6





Clinical Findings – Age 7 ISNCSCI Examination

ASIA
AMERICAN SPINAL INJURY ASSOCIATION

INTERNATIONAL STANDARDS FOR NEUROLOGICAL
CLASSIFICATION OF SPINAL CORD INJURY
(ISNCSCI)

ISCOS
INTERNATIONAL SPINAL CORD SOCIETY

Patient Name _____ Date/Time of Exam _____

Examiner Name _____ Signature _____

RIGHT

MOTOR KEY MUSCLES

SENSORY KEY SENSORY POINTS Light Touch (LT) Pin Prick (PP)

UER
(Upper Extremity Right)

Elbow flexors **C5**
Wrist extensors **C6**
Elbow extensors **C7**
Finger flexors **C8**
Finger abductors (little finger) **T1**

C2	2	2
C3	2	2
C4	2	2
C5	5	2
C6	5	2
C7	5	2
C8	5	2
T1	5	2
T2	2	2
T3	2	2
T4	2	2
T5	2	2
T6	2	2
T7	2	2
T8	2	2
T9	2	2
T10	2	2
T11	2	2
T12	2	2
L1	2	2

Comments (Non-key Muscle? Reason for NT? Pain?):

LER
(Lower Extremity Right)

Hip flexors **L2**
Knee extensors **L3**
Ankle dorsiflexors **L4**
Long toe extensors **L5**
Ankle plantar flexors **S1**

L2	5	0	0
L3	2	0	0
L4	0	0	0
L5	0	0	0
S1	0	0	0
S2	0	0	0
S3	0	0	0
S4-5	0	0	0

(VAC) Voluntary anal contraction (Yes/No) Yes

RIGHT TOTALS	32	40	40
(MAXIMUM)	(50)	(56)	(56)

MOTOR SUBSCORES

UER + UEL = **UEMS TOTAL** (50)
LER + LEL = **LEMS TOTAL** (15)

SENSORY KEY SENSORY POINTS Light Touch (LT) Pin Prick (PP)

MOTOR KEY MUSCLES

LEFT

Elbow flexors **C5**
Wrist extensors **C6**
Elbow extensors **C7**
Finger flexors **C8**
Finger abductors (little finger) **T1**

C2	2	2
C3	2	2
C4	2	2
C5	2	2
C6	2	2
C7	2	2
C8	2	2
T1	2	2
T2	2	2
T3	2	2
T4	2	2
T5	2	2
T6	2	2
T7	2	2
T8	2	2
T9	2	2
T10	2	2
T11	2	2
T12	2	2
L1	2	2
L2	2	2
L3	2	2
L4	2	2
L5	2	2
S1	2	2
S2	2	2
S3	2	2
S4-5	2	2

MOTOR (SCORING ON REVERSE SIDE)

0 = total paralysis
1 = palpable or visible contraction
2 = active movement, gravity eliminated
3 = active movement, against gravity
4 = active movement, against some resistance
5 = active movement, against full resistance
5* = normal corrected for pain/disuse
NT = not testable

SENSORY (SCORING ON REVERSE SIDE)

0 = absent
1 = altered
2 = normal
NT = not testable

L2	5	0	0
L3	3	0	0
L4	0	0	0
L5	0	0	0
S1	0	0	0
S2	0	0	0
S3	0	0	0
S4-5	0	0	0

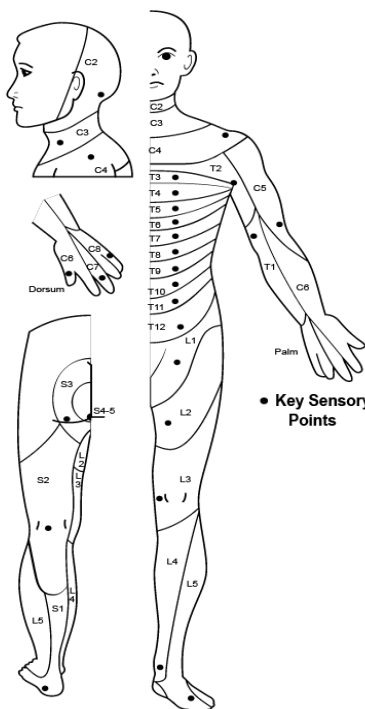
(DAP) Deep anal pressure (Yes/No) Yes

LEFT TOTALS	39	38	33
(MAXIMUM)	(56)	(56)	(50)

SENSORY SUBSCORES

LTR + LTL = **LT TOTAL** (112)
PPR + PPL = **PP TOTAL** (112)

NEUROLOGICAL LEVELS Steps 1-5 for classification as on reverse	R L	1. SENSORY <input type="text" value="L1"/> <input type="text" value="T12"/>	2. MOTOR <input type="text" value="L2"/> <input type="text" value="T12"/>	3. NEUROLOGICAL LEVEL OF INJURY (NLI) <input type="text" value="T12"/>	4. COMPLETE OR INCOMPLETE? Incomplete = Any sensory or motor function in S4-5 <input type="text" value="I"/>	5. ASIA IMPAIRMENT SCALE (AIS) <input type="text" value="C"/>	(In complete injuries only) ZONE OF PARTIAL PRESERVATION Most caudal level with any innervation	SENSORY <input type="text" value="NA"/> <input type="text" value="NA"/>	MOTOR <input type="text" value="NA"/> <input type="text" value="NA"/>
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Clinical Findings – Age 7

ISNCSCI Examination

Right Lower Extremity		Left Lower Extremity	
L2	5/5	L2	5/5
L3	2/5	L3	3/5
L4	0/5	L4	0/5
L5	0/5	L5	0/5
S1	0/5	S1	0/5

Age 7

Therapeutic Intervention

- OP PT 1x per week x 6 months (then family relocated)
- GT with SC-RGO

Progression of Ambulation

- SC-RGO
- **Posterior** rolling walker → increased distance and consistency with knee flexion-extension
- 650 ft with posterior RW and CGA
- 150 ft with forearm crutches and min A



Clinical Findings – Age 8

Right Lower Extremity	Left Lower Extremity
Hip flexion 4/5	Hip flexion 4/5
Hip adduction 2/5	Hip adduction 2/5
Hip abduction 1+/5	Hip abduction 2/5
Hip extension 1/5	Hip extension 1/5
Knee extension 1+/5	Knee extension 3/5
Knee flexion NT	Knee flexion NT
Ankle DF/PF 0/5	Ankle DF/PF 0/5

Age 8

Therapeutic Intervention

- OP PT daily x 2 weeks during summer
- LE stretching, strengthening
- GT with SC-RGO
- LE adaptive tricycle

Progression of Ambulation

- No significant change in independence with ambulation with SC-RGO

Age 9

Therapeutic Intervention

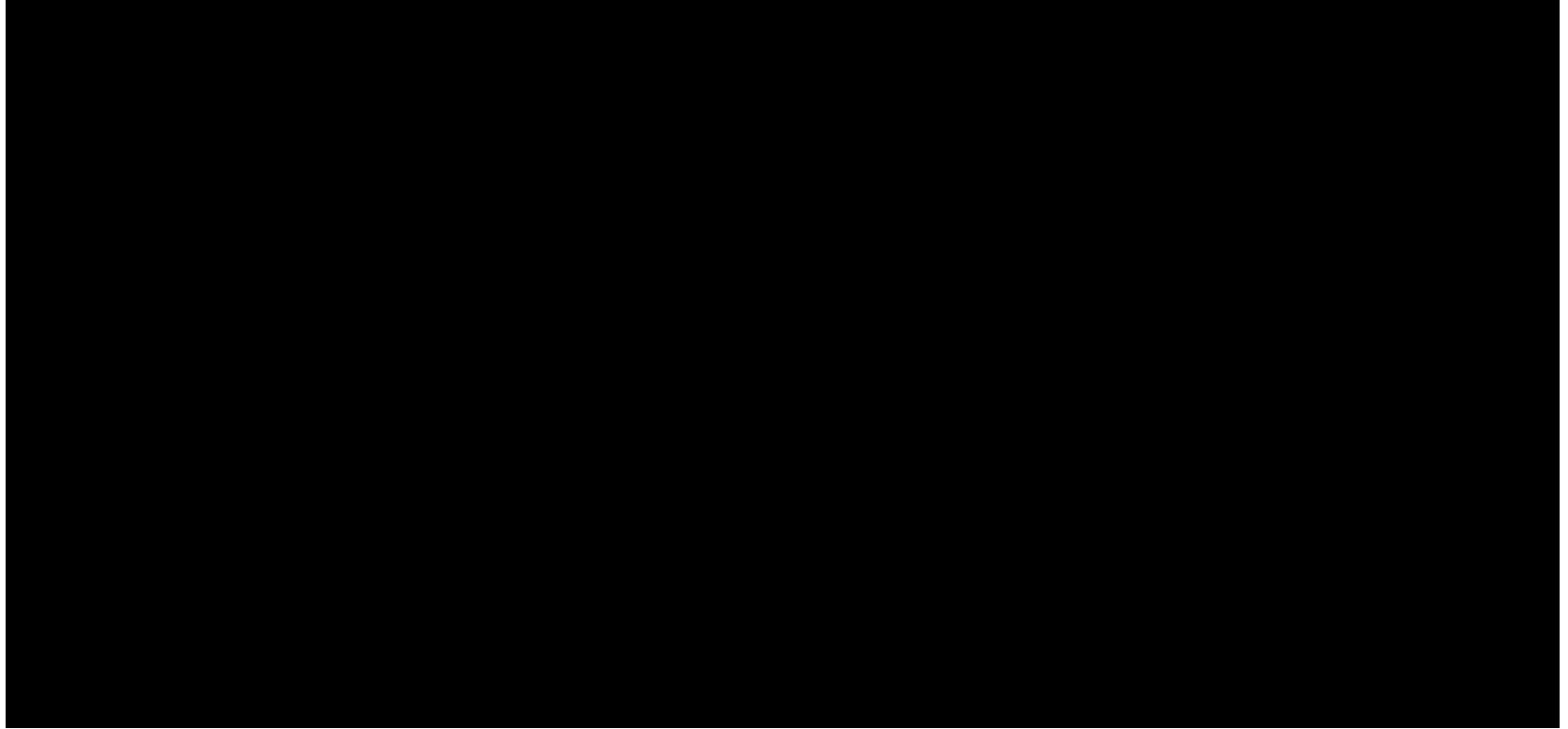
- OP PT daily x 3 weeks during summer
- LE stretching, strengthening
- GT with SC-RGO with forearm crutches
- Curbs, ramps, stairs
- LE adaptive tricycle

Progression of Ambulation

- SC-RGO, independent with PRW > **1000 ft**
- 325 ft with forearm crutches and CG to min A level surfaces, curbs, ramps



Reciprocal Gait with SC-RGO – Age 9





Outcomes

- Child ambulates at home therapeutically with SC-RGO and posterior RW or crutches
- Family's reported goal continues to be community level ambulation



Discussion

- Progression of ambulation from a less functional swing-to gait pattern to a more functional reciprocal gait pattern was influenced over time by:
 - Recovery of motor function
 - Changes in range of motion of the hips
 - The child's age and maturity level to ensure adequate attention-to-task as is needed to use an SC-RGO



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