Central Cord Syndrome

New Definitions For an Old Syndrome

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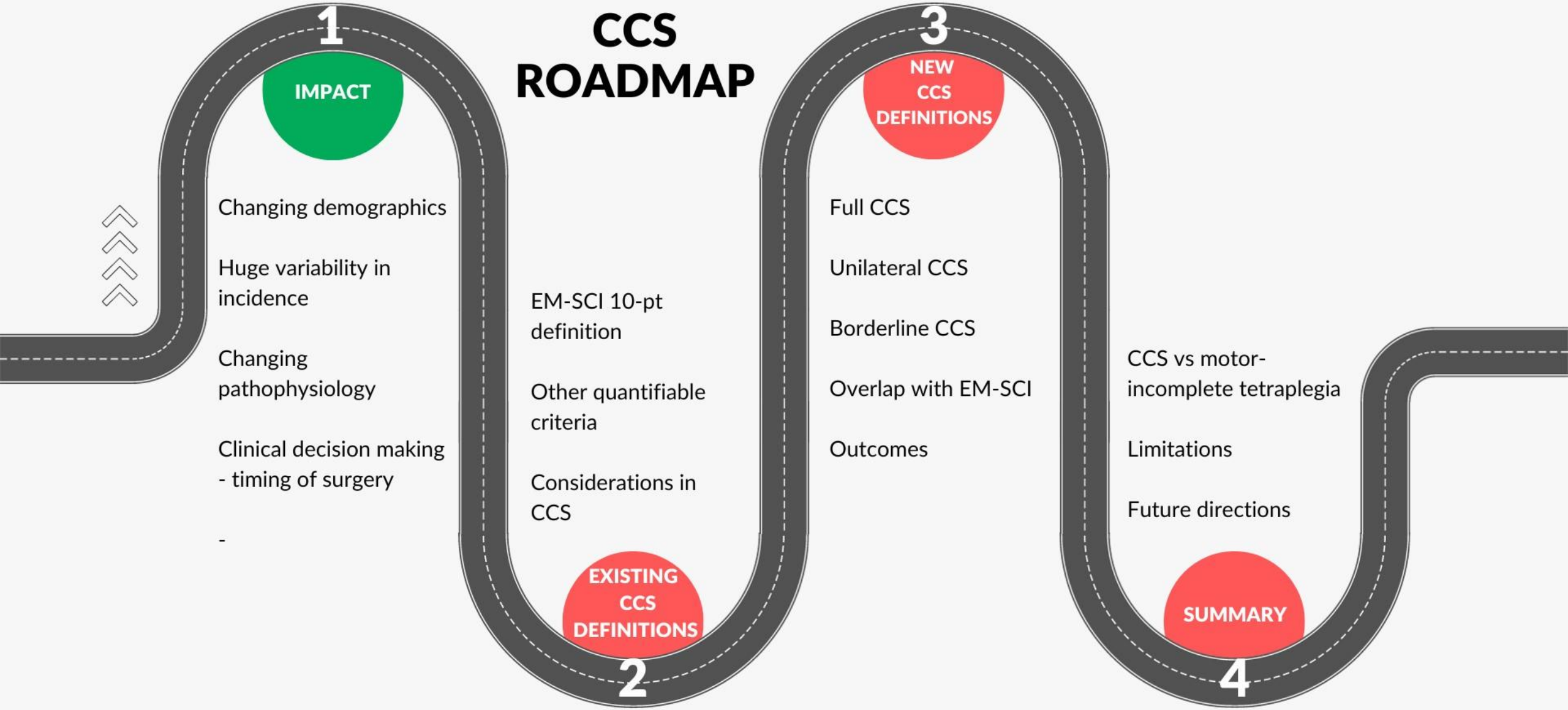
D I S C L O S U R E S

The Devivo Mentored Research Award 2022 provided support for some of the work showcased in this presentation.

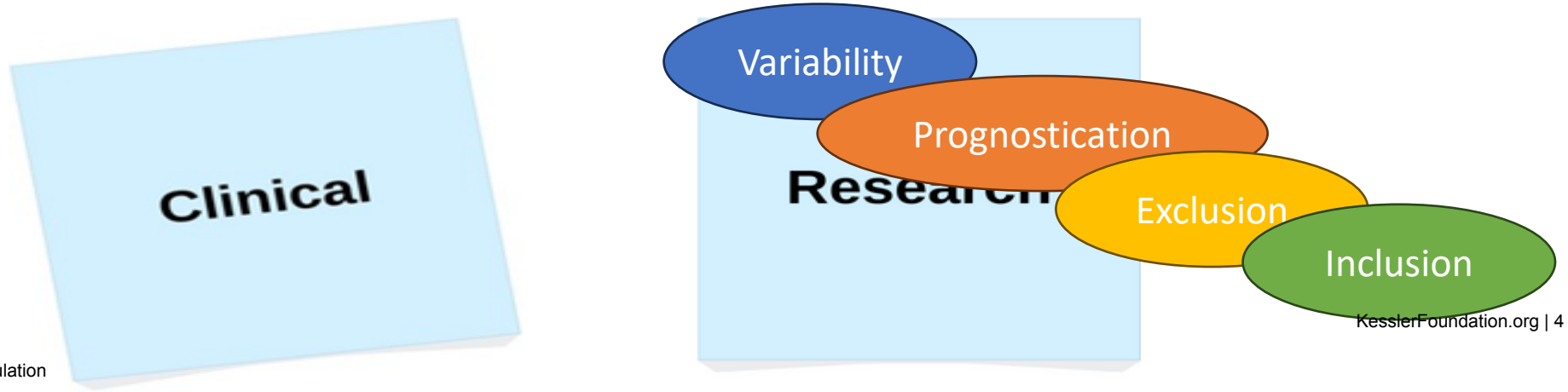
CCS ROADMAP


1
IMPACT
Changing demographics
Huge variability in incidence
Changing pathophysiology
Clinical decision making - timing of surgery
-
2
EXISTING CCS DEFINITIONS
EM-SCI 10-pt definition
Other quantifiable criteria
Considerations in CCS
3
NEW CCS DEFINITIONS
Full CCS
Unilateral CCS
Borderline CCS
Overlap with EM-SCI
Outcomes
4
SUMMARY
CCS vs motor-incomplete tetraplegia
Limitations
Future directions

CENTRAL CORD SYNDROME (CCS)

"Disproportionately more motor impairment of the upper than of the lower extremities, bladder dysfunction, usually urinary retention, and varying degrees of sensory loss below the level of the lesion"

Schneider, 1954

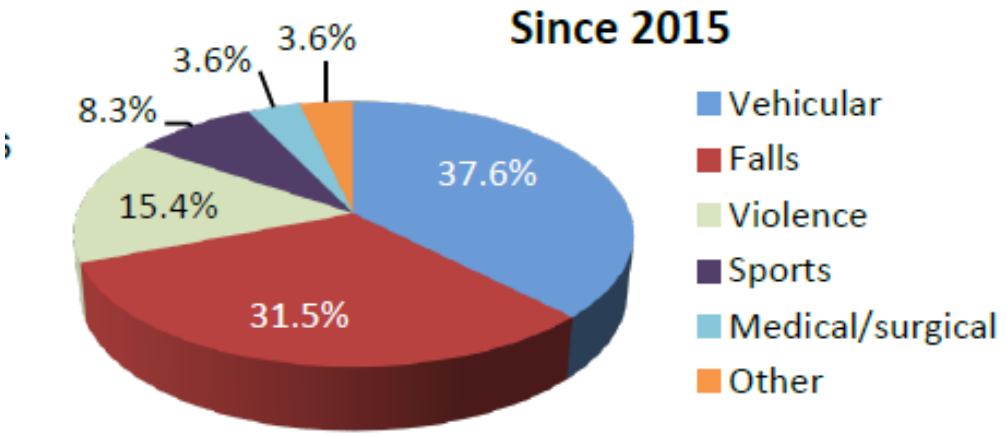


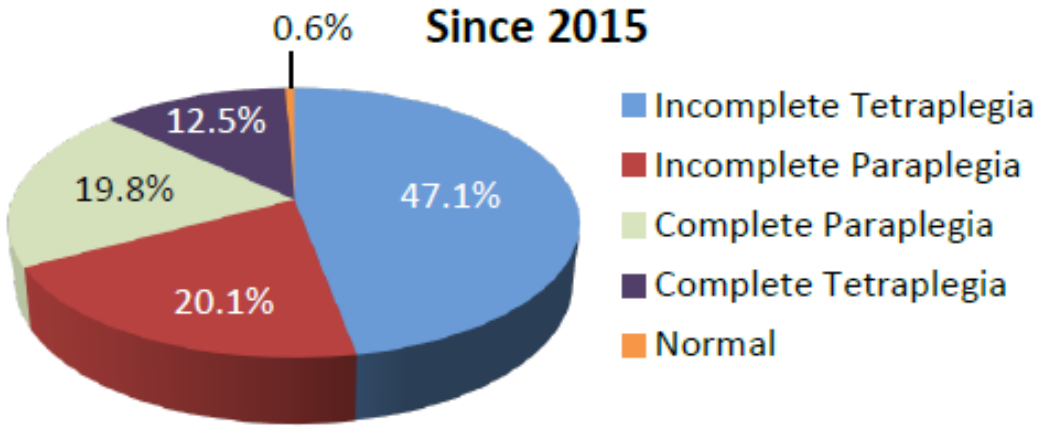
IMPACT

Most common syndrome
Changing demographics
Huge variability in incidence
Changing pathophysiology
Clinical decision making - timing of surgery

CHANGING DEMOGRAPHICS

Year of Injury	Age at Injury			
	N	Mean	Standard Deviation	Minim
1972-1979	4,562	28.7	14.1	
1980-1984	4,949	30.5	14.7	
1985-1989	3,843	32.3	15.8	
1990-1994	3,295	33.7	16.0	
1995-1999	3,623	36.4	17.0	
2000-2004	3,443	37.6	16.7	
2005-2009	3,606	40.5	18.0	
2010-2014	2,947	42.3	18.3	
2015-2020	4,465	43.2	18.5	
Total	34,733	35.8	17.3	





National Spinal Cord Injury Statistical Center, 2021;
Traumatic SCI Facts & Figures at a glance, 2023

INCIDENCE – TRAUMATIC SCI[a]

AUTHORS, YEAR	PARTICIPANTS	CCS	BSS	ACS
Shrosbree, 1977	955	99 (10%)	--	--
Bracken, 1978	133	--	4 (3%)	--
Pickett, 2006[2]	151	49 (32%)	6 (4%)	17 (11%)
McKinley, 2007	839	77 (9%)	30 (4%)	8 (1%)
Lenehan, 2009	807	50 (6%)	--	--
Pouw, 2011	916	97 (11%)*	--	--
Furusawa, 2012	2,413	186 (8%)*	--	--
Kepler, 2015	426	80 (19%)	--	--
Thompson, 2015	831	241(29%)	--	--
Engel-Haber, 2022	3,639	499 (14%)*	71 (2%)	236 (6.5%)

Engel-Haber, 2022

[a]

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Engel-Haber, 2022

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Engel-Haber, 2022

[a]

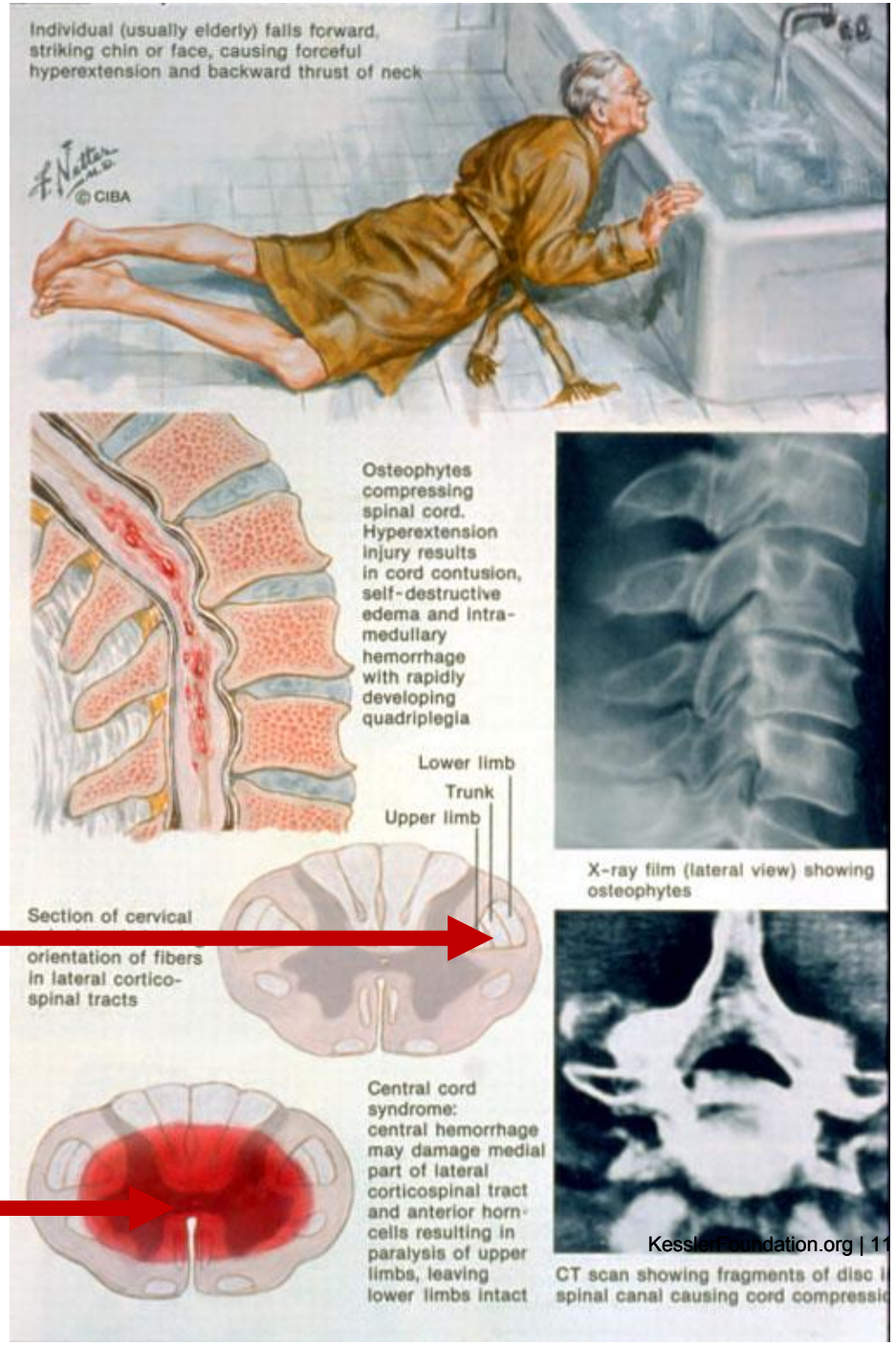
INCIDENCE – INCOMPLETE TETRAPLEGIA[a]

AUTHORS, YEAR	PARTICIPANTS	CCS	BSS	ACS
Bosch, 1971	60	42 (70%)	5 (8%)	12 (20%)
Bohlman, 1979	85	15 (18%)	8 (9%)	51 (60%)
Pollard, 2003	412	97 (24%)	66 (16%)	190 (46%)
Pouw, 2010	228	--	52 (23%)‡	--
Pouw, 2011	248	97 (39%)*	--	--
Badhiwala, 2020	801	185 (23%)*	--	--
Engel-Haber, 2022	1,649	499 (30%)*	55 (3%)	169 (10%)

Engel-Haber, 2022

a

CHANGING PATHOPHYSIOLOGY



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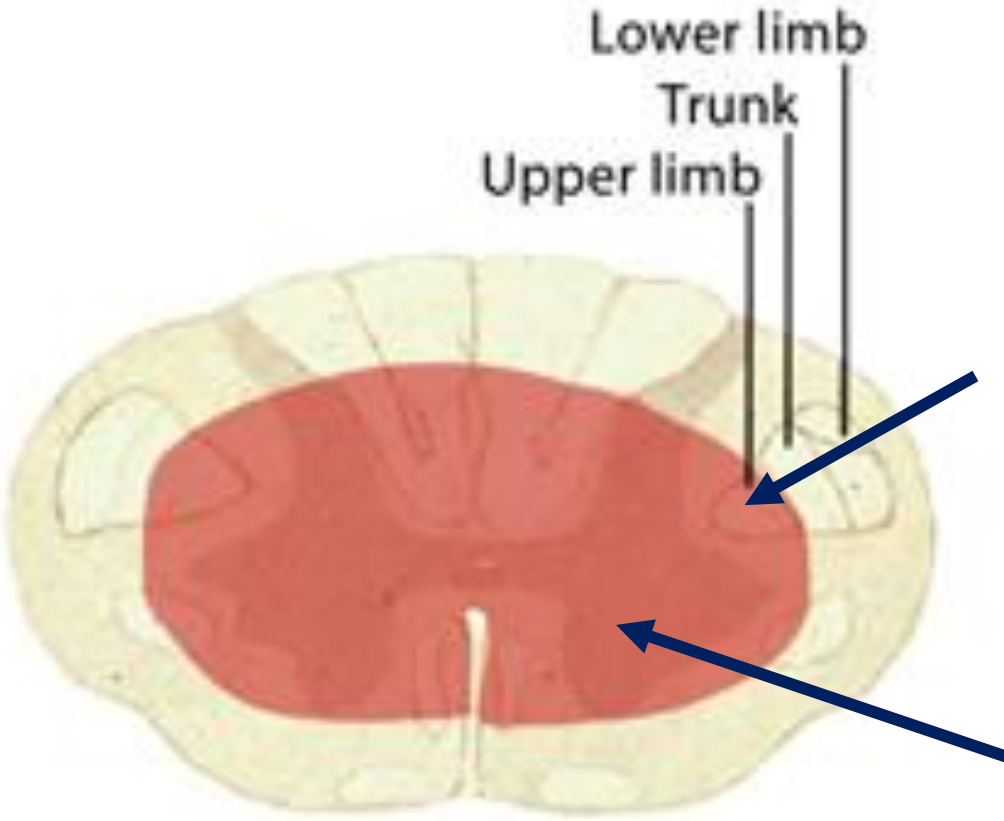
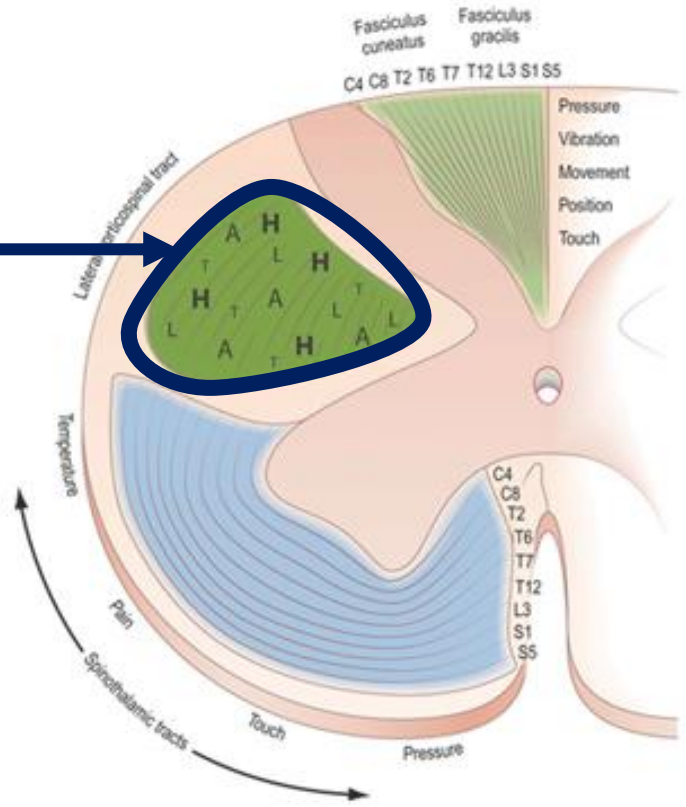


Corticospinal tract



Levi, 2022

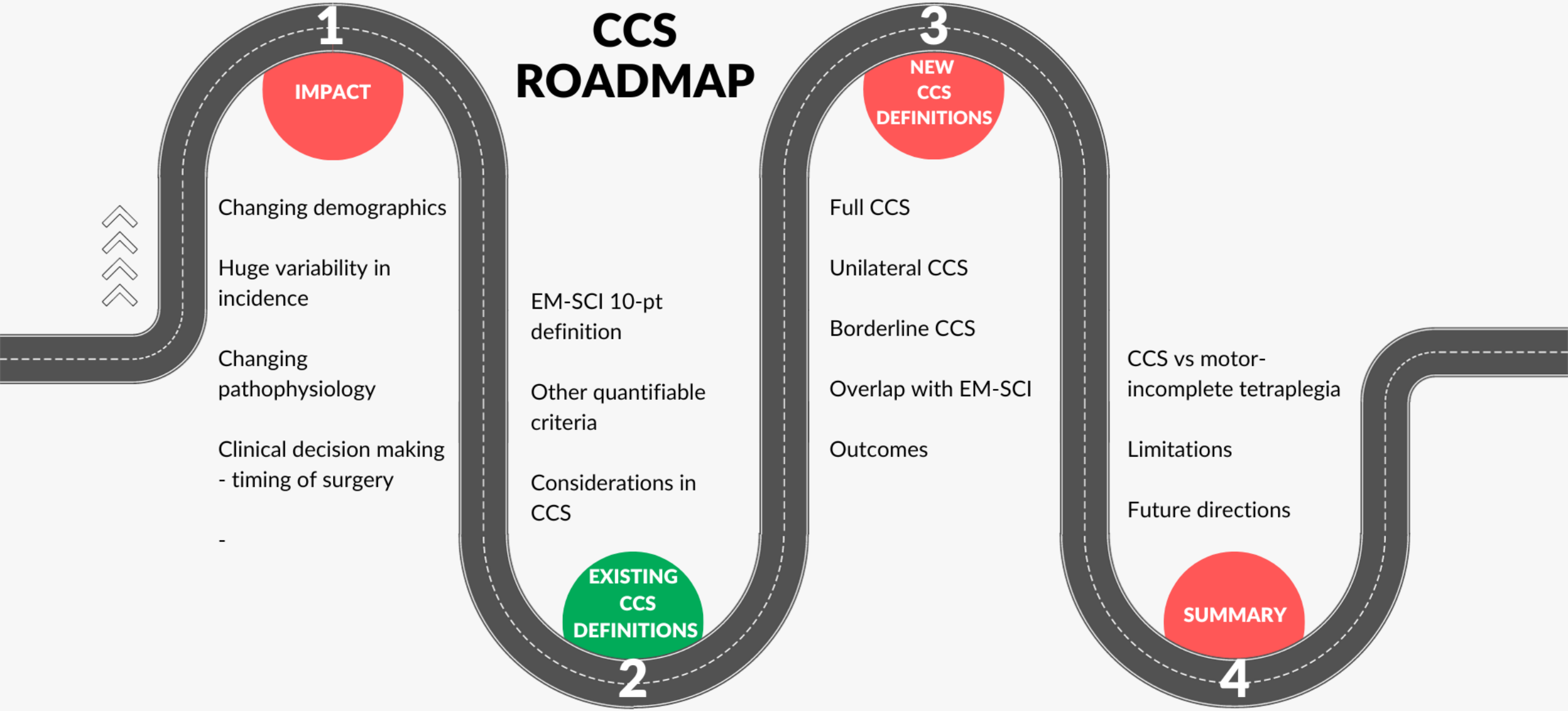
TIMING OF SURGERY - DEBATE

"Natural history is favorable. Operative intervention leads to poorer neurological recovery."
Schneider, 1954

"Early operative management (<24 h) Improves neurological and functional recovery."
Fehlings, 2012

"Early surgical decompression (<12 h) does not result in statistically significant or clinically meaningful neurological improvement."
Hosman, 2023

CCS ROADMAP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EXISTING CCS DEFINITIONS[a]

EM-SCI:

LEMS – UEMS ≥ 10[b]

[a]Engel-Haber, 2023 [b]van Middendorp, 2010;

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Engel-Haber, 2022

EXISTING CCS DEFINITIONS[a]

EM-SCI:

LEMS – UEMS ≥ 10[b]

also: LEMS – UEMS ≥ 1[c], 5[d] or 19[e]

[a]Engel-Haber, 2023 [b]van Middendorp, 2010;
[c]Waters, 1996; [d]Badhiwala, 2022; [e]Wirz, 2010;

EM-SCI: LEMS – UEMS ≥ 10

Myotomes	Right	Left
C5	2	3
C6	2	2
C7	2	3
C8	1	1
T1	1	1
Total UEMS	**18**	
L2	4	4
L3	4	4
L4	4	4
L5	4	4
S1	4	4
Total LEMS	**40**	

40 – 18 > 10

Myotomes	Right	Left
C5	1	2
C6	1	2
C7	1	3
C8	1	1
T1	1	1
Total UEMS	14	
L2	5	5
L3	5	5
L4	5	5
L5	5	5
S1	5	5
Total LEMS	50	

50 – 14 > 10

EM-SCI: LEMS – UEMS ≥ 10

Myotomes	Right	Left
C5	2	3
C6	2	2
C7	2	3
C8	1	1
T1	1	1
Total UEMS	18	
L2	4	4
L3	4	4
L4	4	4
L5	4	4
S1	4	4
Total LEMS	40	

Myotomes	Right	Left
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L3	5	5
L4	5	5
L5	5	5
S1	5	5
Total LEMS	50	

Distal (+Proximal?) UE Weakness

Variable LE Strength

Asymmetrical

EM-SCI: LEMS – UEMS ≥ 10

Myotomes	Right	Left
C5	0	0
C6	0	0
C7	0	0
C8	0	0
T1	0	0
Total UEMS	**0**	
L2	0	3
L3	0	3
L4	0	3
L5	0	3
S1	0	3
Total LEMS	**15**	

Myotomes	Right	Left
C5	4	4
C6	4	4
C7	4	4
C8	4	4
T1	4	4
Total UEMS	**40**	
L2	5	5
L3	5	5
L4	5	5
L5	5	5
S1	5	5
Total LEMS	**50**	

Significa
Asymmet

CCS?!

d CCS Case

ADDITIONAL CCS DEFINITIONS

- "Clinical impression of CCS"[a,b]
- CCS described on a continuum[c]:

$$\left(1 - \frac{aUEMS\ below\ NLI}{aLEMS}\right) \times 100 > 10\%$$

'Central myelopathy index (CMI)' describes the same ratio[d].

Consistency in Research

'CCSness' 0%-100%

[a]Schroeder, 2015; [b]Guest, 2002; [c]Hayes, 2000 [d]Blasetti, 2020

ADDITIONAL CCS DEFINITIONS

$$\left(1 - \frac{aUEMS\ Below\ NLI}{aLEMS}\right) \times 100 > 10\%$$

0

Myotomes	Right		Left
C5	5		5
C6	5		5
C7	5		5
C8	0		0
T1	0		0
Total UEMS		**30**	
L2	2		2
L3	4		4
L4	2		2
L5	2		2
S1	2		2
Total LEMS		**24**	

CONSIDERATIONS IN CCS[a]

Distal vs Proximal UE Weakness

Asymmetrical Weakness

Disproportionate Weakness

AIS Grades Used in Definition

Imaging / Injury Mechanism Used in Definition

[a]Engel-Haber, 2023

CONSIDERATIONS IN CCS[a]

Distal vs Proximal UE Weakness

Asymmetrical Weakness

AIS Grades Used in Definition

Imaging / Injury Mechanism Used in Definition

Engel-Haber, 2023

"Any type of acute sensory or motor deficit localized to the cervical spinal cord from a traumatic event in the **absence of fracture or dislocation**". Avila, 2021

"**Radiographic** and/or clinical presence of a cervical SCI **without ongoing compression**, which most often occurred after acute trauma in the setting of **pre-existing spondylosis and a narrowed canal**". Lessing, 2020

[a] Defining and Decoding Central Cord Syndrome
Einat Haber, MD, Associate Research scientist
Tim and Caroline Reynolds Center for Spinal Stimulation, Kessler Foundation

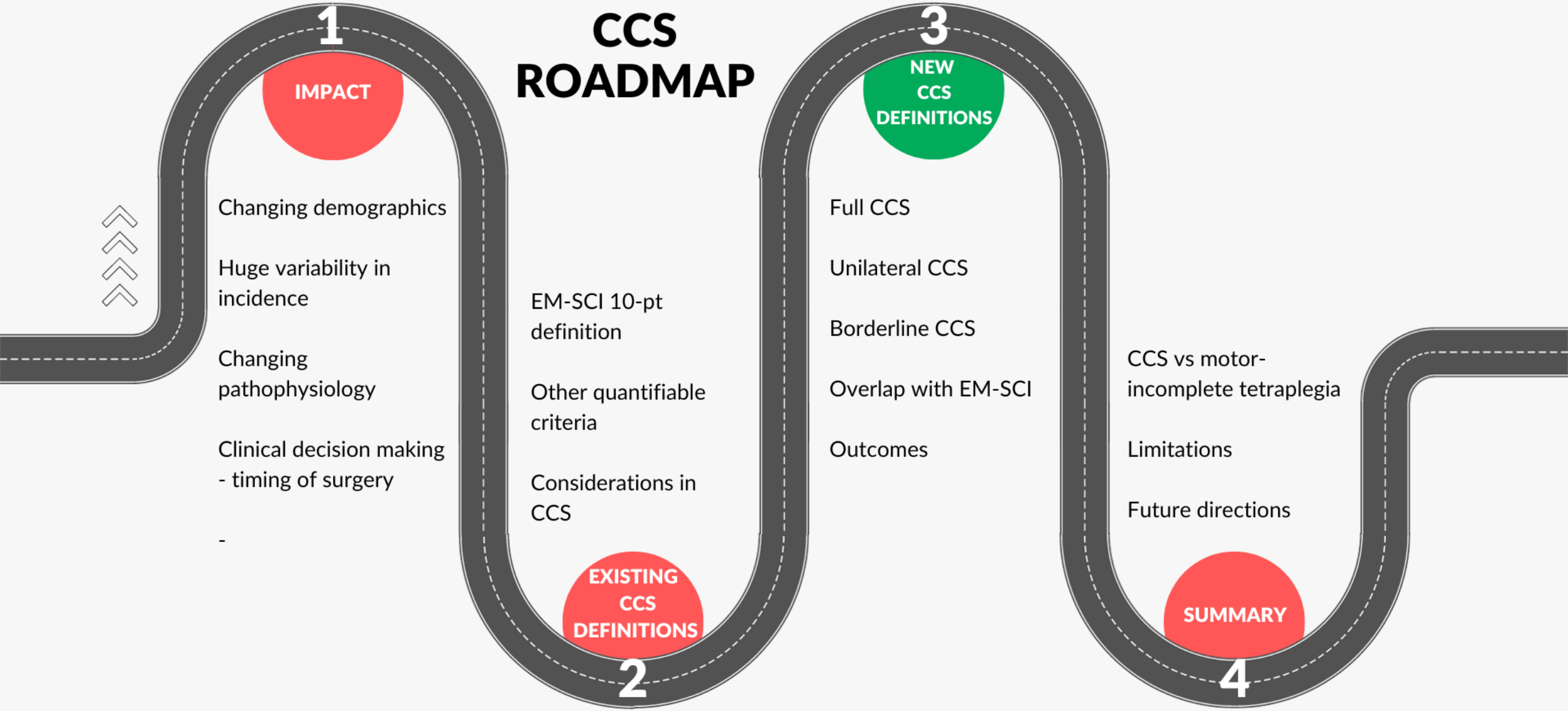
KesslerFoundation.org | 24 of 41

SUMMARY THUS FAR…

- The clinical diagnosis is deeply embedded in the clinical field
- Significant variation observed
- We support previous calls to revise the definition of CCS[a,b]

[a]Smith, 2021; [b]Badhiwala, 2020

CCS ROADMAP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OBJECTIVES & METHODS

"Defining New, Quantifiable Criteria for Central Cord Syndrome"

- Objectives:
  1. Define different clinical variations of CCS
  2. Assess frequency, overlap with existing criteria
  3. Compare outcomes

OBJECTIVES & METHODS

"Defining New, Quantifiable Criteria for Central Cord Syndrome"

- Objectives:
  1. Define different clinical variations of CCS
  2. Assess frequency, overlap with existing criteria
  3. Compare outcomes
- SCIMS database (2010-2020)
- N=1,490 – individuals with motor incomplete tetraplegia (=Cervical with AIS C or D)
- Statistical analysis: descriptive, comparative (Chi-square, ANOVA)

PROPOSED CCS SUBSETS

- Distal UE weakness
- Extent of symmetry

Type	Definition
Full (bilateral) CCS	(avg right LE – avg right distal UE) ≥ 2 **AND** (avg left LE – avg left distal UE) ≥ 2
Unilateral CCS	(avg right LE – avg right distal UE) ≥ 2 **OR** (avg left LE – avg left distal UE) ≥ 2
Borderline CCS	1 ≤ (avg right LE – avg right distal UE) < 2 **AND** 1 ≤ (avg left LE – avg left distal UE) < 2

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- Distal UE weakness
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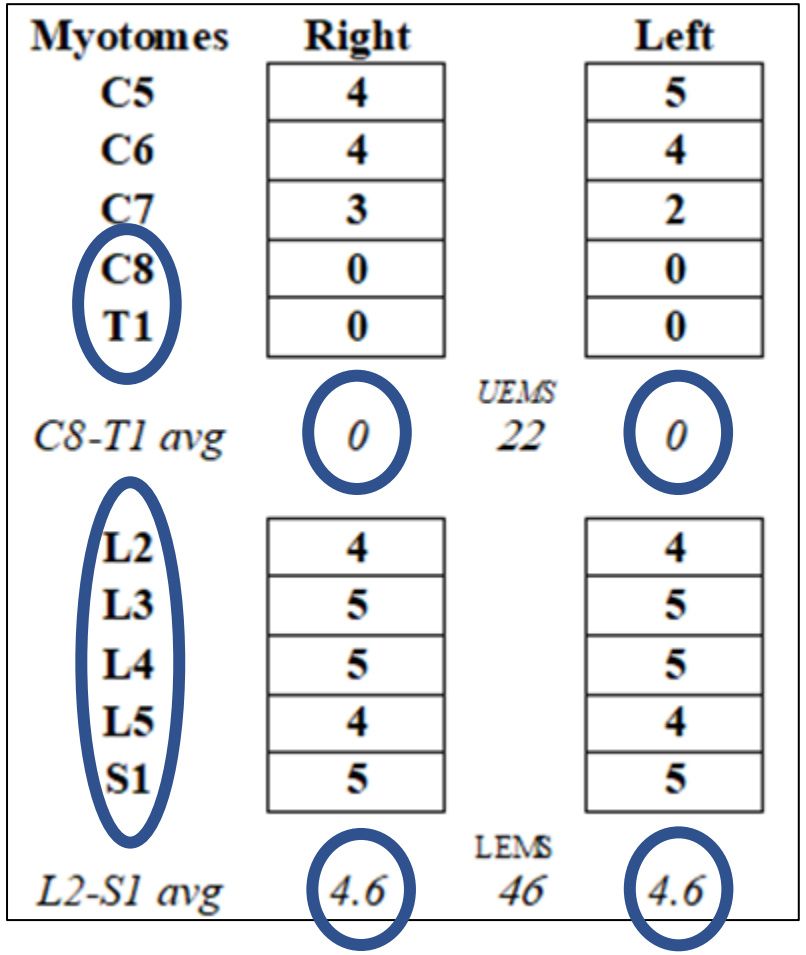
FULL CCS

(avg right LE – avg right distal UE) ≥ 2

AND

(avg left LE – avg left distal UE) ≥ 2



Myotomes	Right	Left
C5	4	5
C6	4	4
C7	3	2
C8	0	0
T1	0	0
C8-T1 avg	*0*	*0*
	UEMS 22	
L2	4	4
L3	5	5
L4	5	5
L5	4	4
S1	5	5
L2-S1 avg	*4.6*	*4.6*
	LEMS 46	

UNILATERAL CCS

(avg right LE – avg right distal UE) ≥ 2

OR

(avg left LE – avg left distal UE) ≥ 2

Myotomes	Right		Left
C5	0		5
C6	0		5
C7	0		5
C8	1		5
T1	0		5
		UEMS	
C8-T1 avg	*0.5*	*26*	*5*
L2	4		5
L3	5		5
L4	4		5
L5	4		5
S1	4		5
		LEMS	
L2-S1 avg	*4.2*	*46*	*5*

Myotomes	Right		Left
C5	2		0
C6	2		0
C7	2		0
C8	2		0
T1	2		0
		UEMS	
C8-T1 avg	*2*	*10*	*0*
L2	4		1
L3	5		0
L4	5		0
L5	5		0
S1	5		0
		LEMS	
L2-S1 avg	*4.8*	*25*	*0.2*

CCS?!

BORDERLINE CCS

1 ≤ (avg right LE – avg right distal UE) < 2

AND

1 ≤ (avg left LE – avg left distal UE) < 2

Myotomes	Right		Left
C5	4		4
C6	4		4
C7	4		4
C8	4		4
T1	4		4
C8-T1 avg	*4*	*UEMS 40*	*4*
L2	5		5
L3	5		5
L4	5		5
L5	5		5
S1	5		5
L2-S1 avg	*5*	*LEMS 50*	*5*

Myotomes	Right		Left
C5	0		1
C6	0		0
C7	1		0
C8	0		0
T1	0		0
C8-T1 avg	*0.2*	*UEMS 2*	*0.2*
L2	1		1
L3	2		2
L4	1		1
L5	1		1
S1	1		1
L2-S1 avg	*1.2*	*LEMS 12*	*1.2*

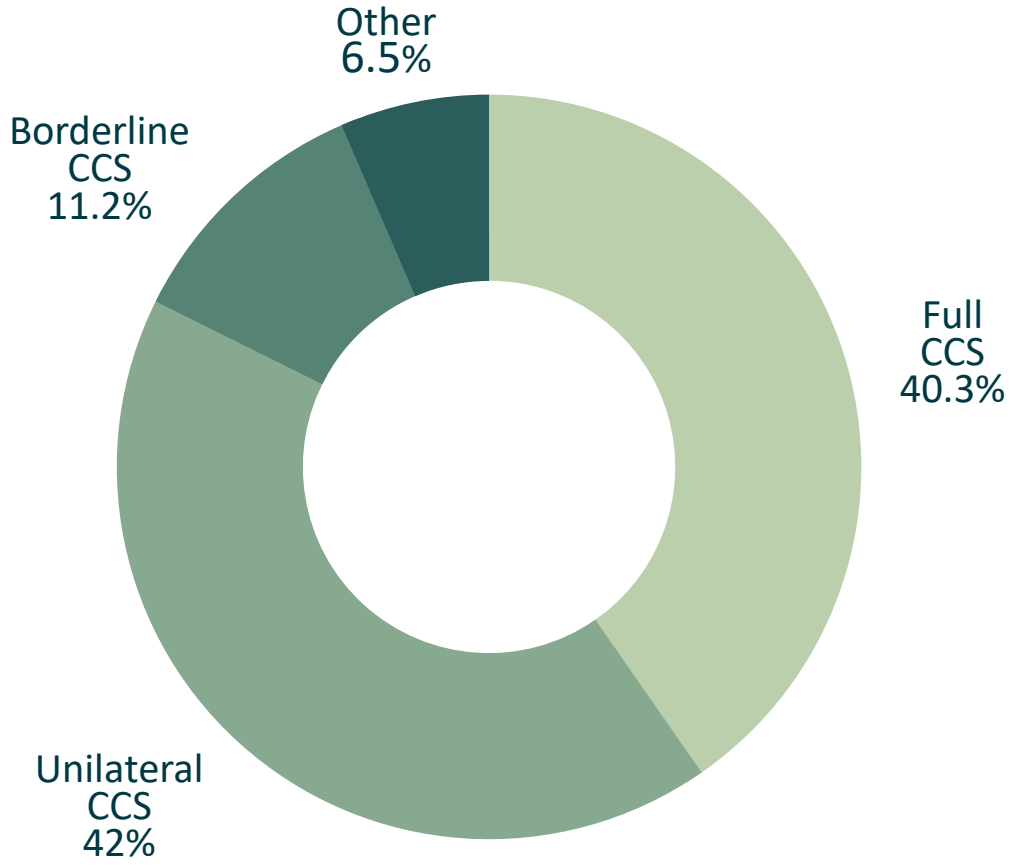
RESULTS

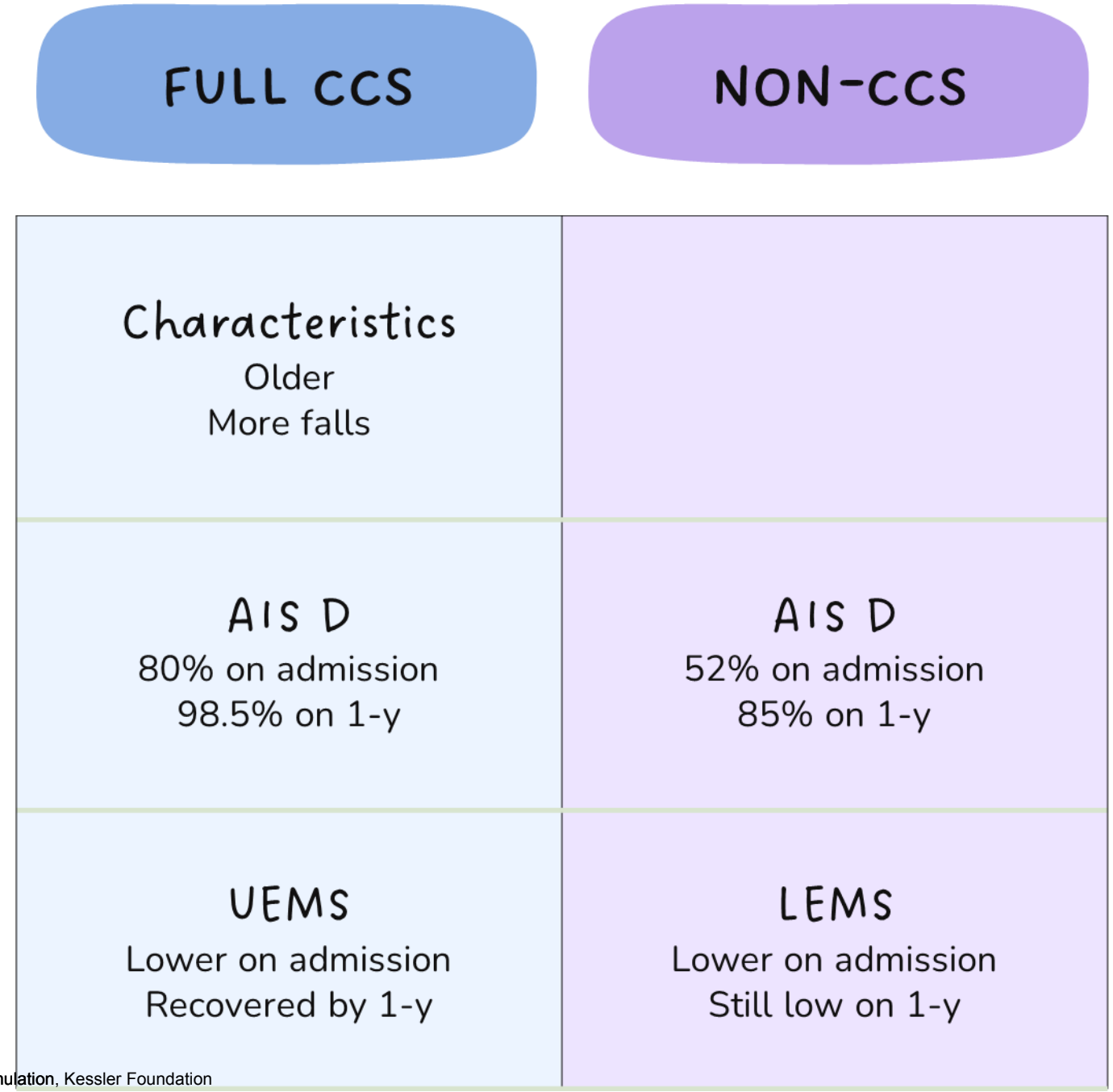
- N=1490 with motor incomplete tetraplegia
- 52% had some variant of CCS:
  - 17.5% with full CCS
  - 25.6% with unilateral CCS
  - 9% with borderline CCS

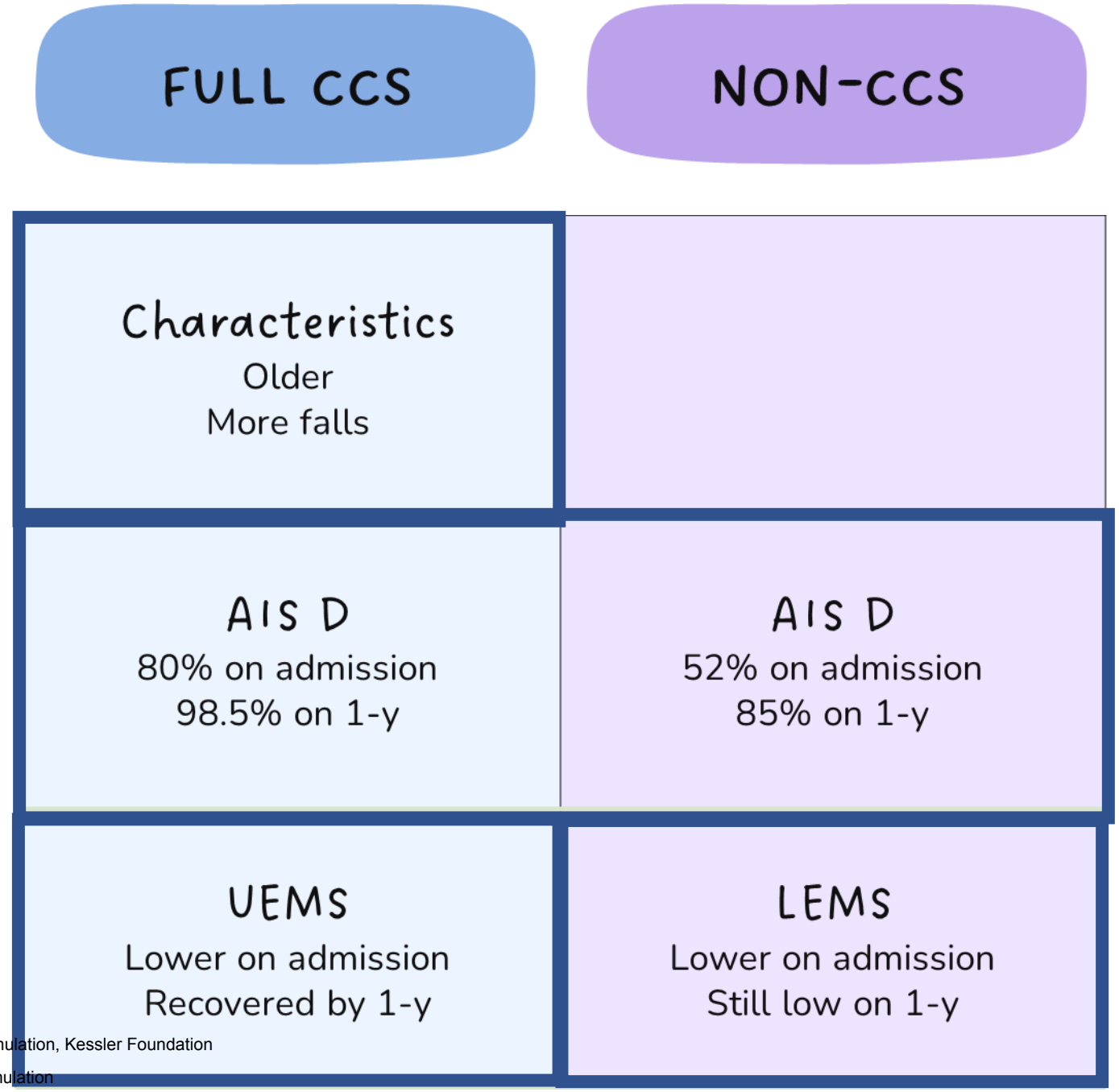
OVERLAP WITH EM-SCI

- N=582 (39%) fulfilled the EM-SCI criteria (LEMS – UEMS ≥ 10)

- Incomplete coverage. Not captured by the EM-SCI criteria:
  - 10% of full CCS
  - 36% of unilateral CCS
  - 52% of borderline CCS



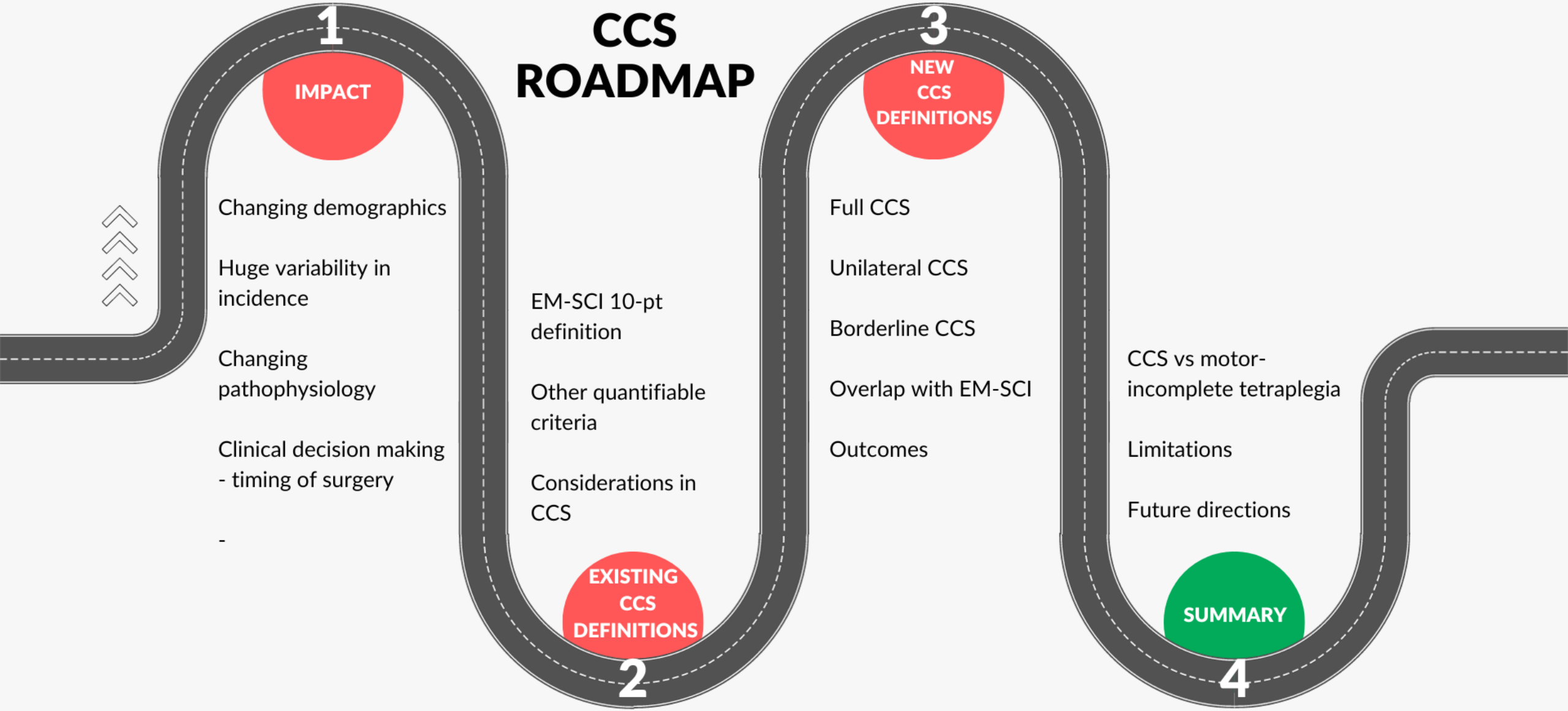

FULL CCS
NON-CCS
Characteristics
Older
More falls
AIS D
80% on admission
98.5% on 1-y
AIS D
52% on admission
85% on 1-y
UEMS
Lower on admission
Recovered by 1-y
LEMS
Lower on admission
Still low on 1-y



Functional Differences?

Defining and Decoding Central Cord Syndrome
Einat Haber, MD, Associate Research scientist

CCS ROADMAP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DISCUSSION & CONCLUSIONS

- Instead of a one-size-fits-all approach definition → delineated the most common variations
- Is it really a syndrome?

  In motor incomplete tetraplegia:
  - 52% with any CCS (17.5% full CCS)
  - 66% with UEMS<LEMS (!!)

DISCUSSION & CONCLUSIONS

- Limitations:
  - 1-year functional data not available on SCIMS
  - Still significant variation
- No clear reason to exclude CCS from studies
- Clinical & research benefits
- Needs review and validation

THANK YOU