Cause of death dependencies: structure and impact of hypothetical disruptions

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Cause of death dependencies

Figure: Odds ratios (OR) between major groups of causes of death, USA, 2019
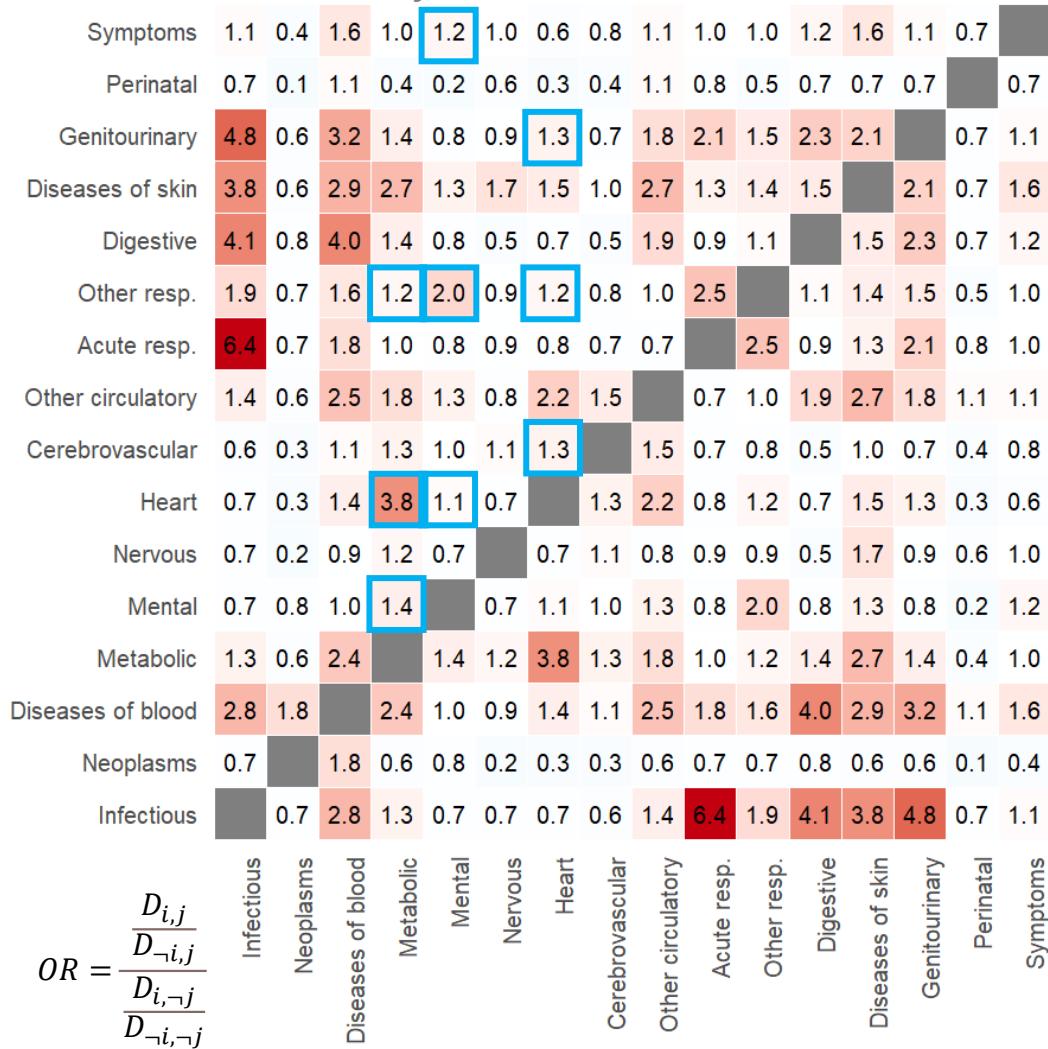
Figure: Index of odds ratios (base = 2000), leading cause of death pairs, USA, 2000–2019
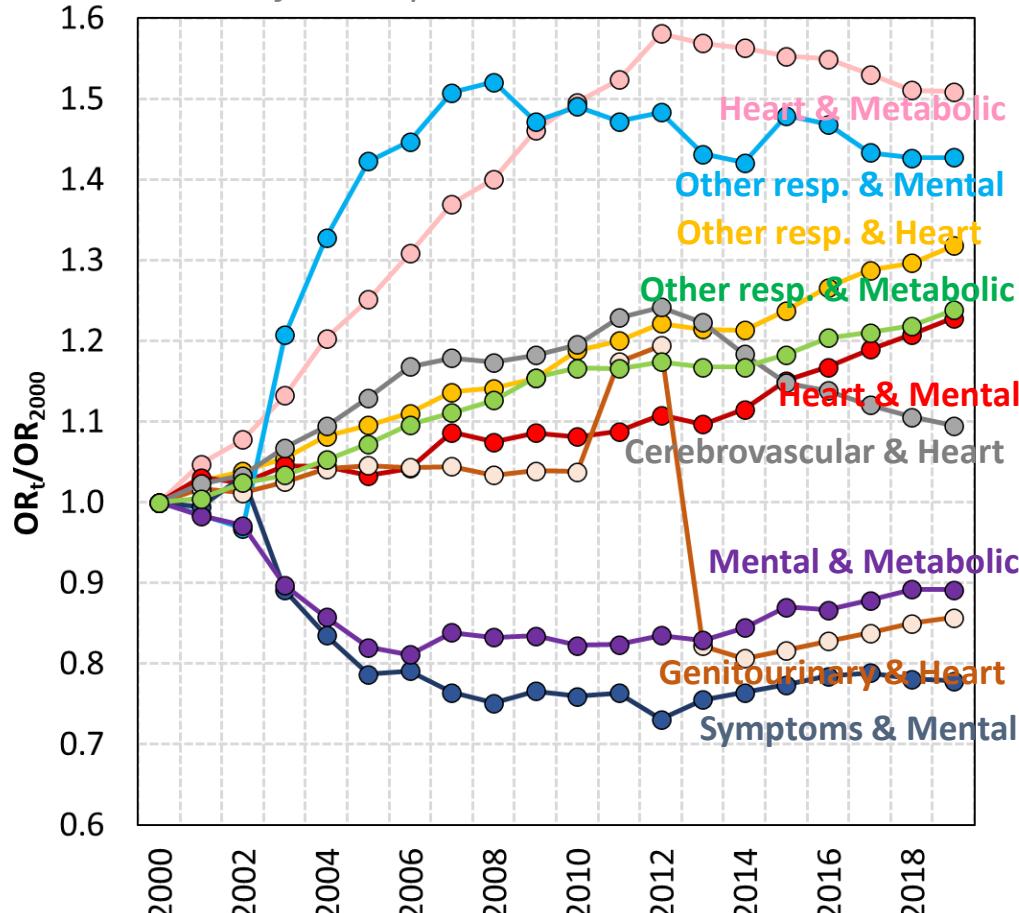
70% of deaths are due to 9 leading cause of death pairs

$$OR = \frac{\dfrac{D_{i,j}}{D_{\neg i,j}}}{\dfrac{D_{i,\neg j}}{D_{\neg i,\neg j}}}$$

Method of implementing disruptions

- We disrupted the connections between diseases within leading cause of death pairs by optimizing marginal totals within the contingency table.

Figure: One solution for finding independence between diseases i and j

Disease i: Heart disease, disease j: Endocrine, nutritional and metabolic diseases

		Disease j				Observed	Adjusted
		YES	NO				
Disease i	YES	376 200	1 052 256	1 428 456	Odds ratio	3.8010	1.0063
	NO	123 205	1 309 862	1 433 067			
		499 405	2 362 118	2 861 523			

Former X² test:

	$D_{\neg i \neg j}$	$D_{\neg ij}$	$D_{i \neg j}$	D_{ij}	$D_{\neg i}$	D_i	$D_{\neg j}$	D_j	Total	Total
					To be optimized				**Constrain**	
Observed	1 309 862	123 205	1 052 256	376 200	1 433 067	1 428 456	2 362 118	499 405	2 861 523	2 861 523
Expected	1 182 962	250 105	1 179 156	249 300	1 433 067	1 428 456	1 433 067	1 428 456	2 861 523	2 861 523
X2	13 613	64 387	13 657	64 595						
SumX2	156 252 **Target value**									
P-value	<0.000									

X² test adjusted for independence:

	$D_{\neg i \neg j}$	$D_{\neg ij}$	$D_{i \neg j}$	D_{ij}	$D_{\neg i}$	D_i	$D_{\neg j}$	D_j	Total	Total
					To be optimized				**Constrain**	
Observed	936 213	279 305	1 269 805	376 200	1 215 385	1 646 005	2 206 018	655 505	2 861 523	2 861 523
Expected	936 970	278 415	1 268 945	377 060	1 215 385	1 646 005	1 215 385	1 646 005	2 861 390	2 861 390
X2	0.612	2.845	0.582	1.960						
SumX2	6 **Target value**									
P-value	0.1117									
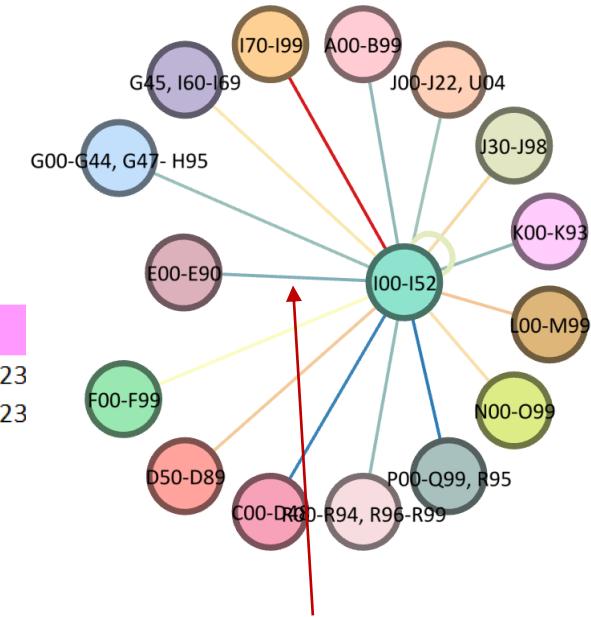
Making independent (*i* and *j*)

What is the effect of disruptions between *i* and *j* on association between *i* and *k*?

Figure: Scenarios of independence between causes i and j (yellow curves)
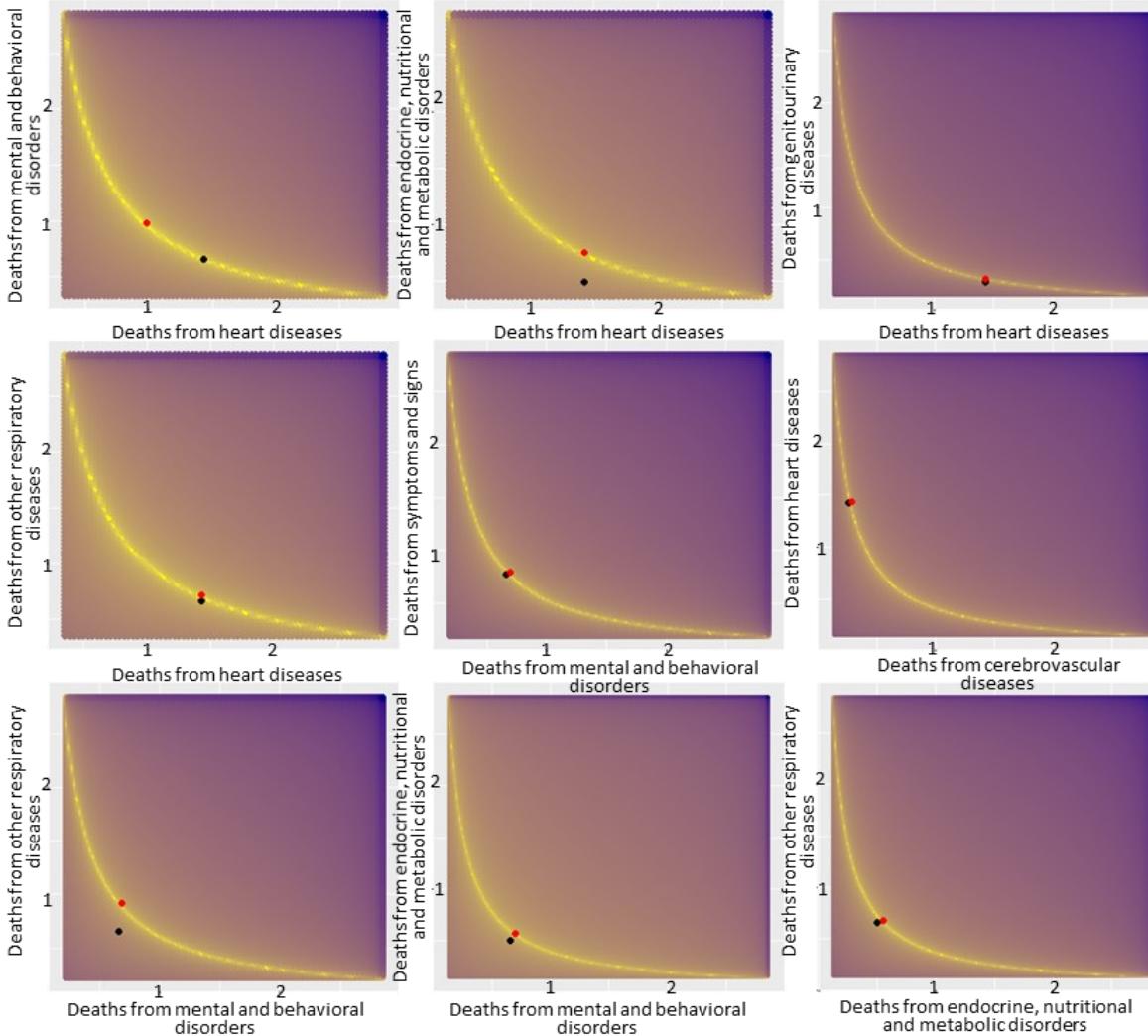
Black dot: original combination of number of deaths from disease i and number of death from disease j

Red dot: „Minimum relocation scenario" (independence scenario applied here)

Death counts on both axes are in 10^6.

Table: Effect of disruption between i and j on associations on i (ratio of original OR and adjusted OR)

Neighbouring disease of i	Cause of death pair (i_j) being dissolved (minimum relocation scenario)								
	Endocrine, nutritional and metabolic diseases + Other respiratory diseases	Mental and behavioral disorders + Other respiratory diseases	Mental and behavioral disorders + Symptoms and signs	Mental and behavioral disorders + Endocrine, nutritional and metabolic diseases	Heart diseases + Other respiratory diseases	Heart diseases + Diseases of the genitourinary system and complications of pregnancy, childbirth and puerperium	Heart diseases + Endocrine, nutritional and metabolic diseases	Heart diseases + Mental and behavioral disorders	Cerebrovascular diseases + Heart diseases
Infectious	1.15 (0.88)	0.67 (0.96)	0.64 (0.92)	0.64 (0.92)	0.70 (1.00)	0.70 (0.99)	0.70 (1.00)	1.42 (2.03)	0.51 (0.88)
Neoplasms	0.50 (0.87)	0.78 (0.95)	0.74 (0.91)	0.74 (0.91)	0.30 (1.00)	0.30 (0.99)	0.30 (1.00)	0.69 (2.30)	0.26 (0.88)
Diseases of blood	2.08 (0.88)	0.91 (0.96)	0.88 (0.92)	0.88 (0.92)	1.45 (1.00)	1.44 (0.99)	1.45 (1.00)	2.82 (1.95)	0.93 (0.88)
Metabolic	()	1.31 (0.95)	1.25 (0.91)	()	3.80 (1.00)	3.78 (0.99)	()	8.81 (2.32)	1.12 (0.86)
Mental	1.18 (0.85)	()	()	()	1.09 (1.00)	1.08 (0.99)	1.09 (1.00)	()	0.90 (0.86)
Nervous	1.05 (0.87)	0.65 (0.95)	0.63 (0.92)	0.63 (0.92)	0.74 (1.00)	0.74 (0.99)	0.74 (1.00)	1.55 (2.09)	0.96 (0.87)
Heart	2.60 (0.68)	1.00 (0.92)	0.93 (0.86)	0.93 (0.86)	()	()	()	()	()
Cerebrovascular	1.15 (0.88)	1.00 (0.95)	0.96 (0.92)	0.96 (0.92)	1.29 (1.00)	1.28 (0.99)	1.29 (1.00)	2.64 (2.05)	()
Other circulatory	1.58 (0.88)	1.23 (0.96)	1.19 (0.92)	1.19 (0.92)	2.18 (1.00)	2.17 (0.99)	2.18 (1.00)	4.30 (1.97)	1.31 (0.88)
Acute resp.	0.87 (0.88)	0.8 (0.96)	0.78 (0.92)	0.78 (0.92)	0.79 (1.00)	0.79 (0.99)	0.79 (1.00)	1.56 (1.97)	0.62 (0.88)
Other resp.	()	()	1.79 (0.90)	1.79 (0.90)	()	1.23 (0.99)	1.24 (1.00)	2.96 (2.38)	0.68 (0.86)
Digestive	1.22 (0.88)	0.72 (0.96)	0.70 (0.92)	0.70 (0.92)	0.71 (1.00)	0.71 (0.99)	0.71 (1.00)	1.44 (2.02)	0.42 (0.88)
Diseases of skin	2.37 (0.88)	1.27 (0.96)	1.22 (0.92)	1.22 (0.92)	1.47 (1.00)	1.47 (0.99)	1.47 (1.00)	2.87 (1.94)	0.91 (0.88)
Genitourinary	1.27 (0.88)	0.74 (0.95)	0.72 (0.92)	0.72 (0.92)	1.32 (1.00)	()	1.32 (1.00)	2.72 (2.06)	0.63 (0.88)
Perinatal	0.36 (0.89)	0.20 (0.96)	0.19 (0.93)	0.19 (0.93)	0.27 (1.00)	0.27 (0.99)	0.27 (1.00)	0.52 (1.91)	0.38 (0.89)
Symptoms	0.82 (0.85)	1.10 (0.94)	()	1.05 (0.90)	0.64 (1.00)	0.64 (0.99)	0.64 (1.00)	1.57 (2.43)	0.66 (0.86)

Table: Effect of disruption between i and j on associations on j (ratio of original OR and adjusted OR)

Neighbouring disease of j	Cause of death pair (i_j) being dissolved (minimum relocation scenario)								
	Endocrine, nutritional and metabolic diseases + Other respiratory diseases	Mental and behavioral disorders + Other respiratory diseases	Mental and behavioral disorders + Symptoms and signs	Mental and behavioral disorders + Endocrine, nutritional and metabolic diseases	Heart diseases + Other respiratory diseases	Heart diseases + Diseases of the genitourinary system and complications of pregnancy, childbirth and puerperium	Heart diseases + Endocrine, nutritional and metabolic diseases	Heart diseases + Mental and behavioral disorders	Cerebrovascular diseases + Heart diseases
Infectious	1.78 (0.96)	1.11 (0.96)	1.11 (0.96)	1.08 (0.96)	1.65 (0.96)	4.04 (0.96)	0.73 (0.96)	0.38 (0.96)	0.70 (0.96)
Neoplasms	0.69 (0.95)	0.41 (0.56)	0.36 (0.96)	0.47 (0.82)	0.64 (0.88)	0.53 (0.86)	0.31 (0.53)	0.40 (0.49)	0.30 (0.99)
Diseases of blood	1.50 (0.96)	0.97 (0.62)	1.55 (0.97)	1.98 (0.84)	1.41 (0.90)	2.82 (0.87)	1.36 (0.58)	0.54 (0.56)	1.44 (0.99)
Metabolic	()	0.70 (0.57)	0.92 (0.96)	()	1.08 (0.88)	1.23 (0.85)	()	0.70 (0.51)	3.77 (0.99)
Mental	1.89 (0.95)	()	()	()	1.73 (0.86)	0.66 (0.85)	0.70 (0.51)	()	1.08 (0.99)
Nervous	0.84 (0.96)	0.52 (0.60)	0.92 (0.96)	0.99 (0.82)	0.78 (0.89)	0.76 (0.87)	0.66 (0.55)	0.37 (0.54)	0.74 (0.99)
Heart	1.15 (0.92)	0.51 (0.41)	0.61 (0.94)	2.26 (0.59)	()	()	()	()	()
Cerebrovascular	0.76 (0.96)	0.48 (0.61)	0.74 (0.96)	1.08 (0.83)	0.71 (0.89)	0.63 (0.87)	0.73 (0.56)	0.57 (0.54)	()
Other circulatory	0.99 (0.96)	0.64 (0.62)	1.07 (0.97)	1.50 (0.84)	0.93 (0.90)	1.54 (0.87)	1.03 (0.58)	0.72 (0.56)	2.17 (0.99)
Acute resp.	2.37 (0.96)	1.51 (0.61)	0.96 (0.97)	0.82 (0.84)	2.21 (0.89)	1.86 (0.87)	0.57 (0.58)	0.47 (0.56)	0.79 (0.99)
Other resp.	()	()	0.94 (0.96)	0.98 (0.80)	()	1.29 (0.84)	0.63 (0.51)	0.93 (0.47)	1.23 (0.99)
Digestive	1.02 (0.96)	0.65 (0.61)	1.14 (0.96)	1.15 (0.83)	0.95 (0.89)	2.03 (0.86)	0.78 (0.56)	0.42 (0.55)	0.71 (0.99)
Diseases of skin	1.30 (0.96)	0.84 (0.62)	1.54 (0.97)	2.25 (0.84)	1.22 (0.90)	1.88 (0.87)	1.55 (0.58)	0.74 (0.56)	1.47 (0.99)
Genitourinary	1.48 (0.96)	0.92 (0.60)	1.09 (0.96)	1.20 (0.83)	1.37 (0.89)	()	0.81 (0.56)	0.42 (0.54)	1.31 (0.99)
Perinatal	0.49 (0.96)	0.32 (0.63)	0.66 (0.97)	0.35 (0.85)	0.46 (0.90)	0.60 (0.88)	0.24 (0.59)	0.12 (0.57)	0.27 (0.99)
Symptoms	0.93 (0.95)	0.53 (0.54)	()	0.77 (0.80)	0.85 (0.87)	0.95 (0.84)	0.49 (0.50)	0.55 (0.47)	0.64 (0.99)