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Does neighbourhood deprivation cause poor health? Within-individual analysis of movers in a prospective cohort study

Markus Jokela[1,2]

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[1]Institute of Behavioural Sciences, University of Helsinki, Helsinki, Finland
[2]Department of Psychology, University of Cambridge, Cambridge, UK

Correspondence to
Dr Markus Jokela, Institute of Behavioural Sciences, Siltavuorenpenger 1A, P O Box 9, University of Helsinki, Helsinki 00014, Finland; markus.jokela@helsinki.fi

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ABSTRACT

Background Neighbourhood deprivation has been associated with poor health. The evidence for social causation, however, remains scarce because selective residential mobility may also create neighbourhood differences. The present study examined whether individuals had poorer health when they were living in a deprived neighbourhood compared to another time when the same individuals were living in a less deprived neighbourhood.

Methods Participants were from the British Household Panel Survey prospective cohort study with 18 annual measurements of residential location and self-reported health outcomes between 1991 and 2009 (n=137 884 person-observations of 17 001 persons in England). Neighbourhood deprivation was assessed concurrently with health outcomes using the Index of Multiple Deprivation at the geographically detailed level of Lower Layer Super Output Areas. The main analyses were replicated in subsamples from Scotland (n=4897) and Wales (n=4442). Multilevel regression was used to separate within-individual and between-individuals associations.

Results Neighbourhood deprivation was associated with poorer self-rated health, and with higher psychological distress, functional health limitations and number of health problems. These associations were almost exclusively due to differences between different individuals rather than within-individual variations related to different neighbourhoods. By contrast, poorer health was associated with lower odds of moving to less deprived neighbourhoods among movers. The analysis was limited by the restricted within-individual variation and measurement imprecision of neighbourhood deprivation.

Conclusions Individuals living in deprived neighbourhoods have poorer health, but it appears that neighbourhood deprivation is not causing poorer health of adults. Instead, neighbourhood health differentials may reflect the more fundamental social inequalities that determine health and ability to move between deprived and non-deprived neighbourhoods.

Compared to people who live in affluent and socially cohesive neighbourhoods, those living in socioeconomically disadvantaged neighbourhoods have poorer physical health,[1 2] higher risk of mental disorders[3 4] and higher mortality rate.[5 6] However, most studies of neighbourhood effects have been based on cross-sectional data[3 7–8] or longitudinal data with only baseline measurement of neighbourhood characteristics.[1 9 10] These studies cannot rule out *social selection* as an alternative explanation for neighbourhood health associations. For example, high socioeconomic status is associated with better health and better opportunities for residential mobility, so neighbourhood health associations might develop because socioeconomically advantaged and disadvantaged individuals select their neighbourhoods differently.[11 12] While this methodological problem has been widely acknowledged in studies of neighbourhood effects, few studies have addressed the problem empirically.[13–15]

In a recent Australian study, people's physical and mental health did was not different when they lived in different neighbourhoods with different levels of socioeconomic disadvantage,[15] suggesting that social causation may not explain the neighbourhood health associations. Following the same methodological approach, the present study examined whether people have poorer health when living in a more deprived neighbourhood compared to another time when the same people are living in a less deprived neighbourhood. Causal effects of neighbourhood deprivation should be observed as within-individual associations in the longitudinal models. The associations were hypothesised to be stronger for self-rated health and psychological distress than for chronic illnesses, because the latter take longer time to develop. Selective residential mobility was assessed by examining whether health status predicted moves to more compared to less deprived neighbourhoods.

METHODS

Participants

The British Household Panel Survey (BHPS) is a prospective cohort study of a nationally representative sample of over 5000 British households with annual follow-ups. The original sample included 10 264 individuals aged 16–97 at baseline in 1991. New participants have been included in the sample over the years if they are born to original sample member, if they have moved into a household in the original sample or if a member of the original sample moves into a new household with one or more new people. The sample was enriched with participants from Scotland and Wales wave nine onwards, and from Northern Ireland wave 11 onwards.

For the present analysis, all adult participants with at least one measurement time between 1991 and 2009 were included in the study (or at least two measurement times for the within-individual analysis), and each participant could contribute up

to 18 annual person-observations across the follow-up time. The neighbourhood deprivation indices have been developed separately for England, Scotland and Wales, and they are not directly comparable. The main results are presented for England because of the largest sample size, with up to n=137 884 person-observations of 17 001 persons (aged 15 to 99, mean=44.9, SD=18.5). Taking into account the participants' different study entrance times, these 17 001 participants could have contributed a total of 239 896 person-observations if all of them had participated in all the study waves after their study entrance (details not shown), so 42.5% of all the possible person-observations were missing due to study attrition. Results for subsamples from Scotland and Wales are reported in online supplementary material.

Measures

Self-rated health over the past 12 months was reported on a 5-point scale (1=Excellent, 5=Very poor). *Psychological distress* was assessed using the 12-item General Health Questionnaire (GHQ-12) that asks the respondent to report symptoms of depression, anxiety and stress-related concerns over the past few weeks. The items were rated on a 4-point scale (0=not at all, 1=no more than usual, 2=rather more than usual, 3=much more than usual) and a continuous sum score was created from these items (range between 0 and 36). *Physical limitations* was created as a sum score of three dichotomous variables: (1) functional health limitations assessed with four items on difficulties in activities of daily living (ie, housework, climbing stairs, dressing and walking for at least 10 min), each item rated on a dichotomous scale (0=no, 1=yes) and the scale was recoded so that 0=no health limitations, 1=one or more health limitations (n=118 187 person-observations of 16 731 persons because these questions were not included in two study waves), (2) work-limiting health conditions reported with the question "Does your health limit the type of work or the amount of work you can do?" (n=121 856 person-observations, 16 792 persons) and (3) whether the participant were registered as a disabled person with Social Services or otherwise (0=not disabled, 1=disabled; n=89 501 person-observations, 14 563 persons). In addition, the participants were asked to indicate (0=no, 1=yes) whether they had different health problems: (1) problems or disability connected with: arms, legs, hands, feet back or neck (including arthritis and rheumatism); (2) difficulty in seeing (other than needing glasses to read normal size print); (3) difficulty in hearing; (4) skin conditions/allergies; (5) chest/breathing problems, asthma, bronchitis; (6) heart/high-blood pressure or blood circulation problems; (7) stomach/liver/kidneys or digestive problems; (8) diabetes; (9) anxiety, depression or bad nerves, psychiatric problems; (10) alcohol or drug-related problems; (11) epilepsy; (l) migraine or frequent headaches. From the 11th follow-up onwards the list also included (m) cancer; and (n) stroke (n=56 627 person-observations, 11 057 persons). These health problems were used to create the variables of *number of health problems* (excluding cancer and stroke), *number of neuropsychiatric illnesses* (sum of items i, j, k and l) and *number of cardiometabolic illnesses* (sum of items f, h, and n; calculated only from wave 11 onwards).

Information on the participant's residential location was recorded as part of the interview and data collection process in each study wave. The addresses were then recoded at the geographically detailed level of Lower Layer Super Output Areas (LSOA). In 2001, England was divided into 32 482 LSOAs, and each LSOA contains between 1000 and 3000 persons (mean=1500 persons per LSOA). Neighbourhood *deprivation* was measured at the level of LSOAs using the 2004 Index of Multiple Deprivation (IMD) which is a weighted area-level aggregation score of seven dimensions of deprivation: income; employment; health and disability; education, skills and training; barriers to housing and services; living environment; and crime. The 2004 IMD has been constructed using 37 indicators from the 2001 Census and other, mostly governmental data sources, with the majority of the data based on information from year 2001. The deprivation scores range from 0.6 to 85.6 (mean=20.8, SD=15.1) with higher scores indicating higher level of economic and social deprivation. For all participants, neighbourhood deprivation was assessed concurrently with the assessment of health outcomes.

In order to test whether the within-individual analysis could correctly identify associations that should most definitely vary within individuals as they live in different neighbourhoods, two additional variables were included as comparison outcomes. Neighbourhood *dissatisfaction* was assessed with the question 'Overall, do you like living in this neighbourhood?' (0=Yes, 1=No; n=136 962 person-observations, 16 965 persons). *Preference to move* was assessed with the question 'If you could choose, would you stay here in your present home or would you prefer to move somewhere else?' (0=Stay here, 1=Prefer to move; n=136 200 person-observations, 16 944 persons). These outcomes should be sensitive to changes in neighbourhood deprivation, so that an individual is less satisfied and more eager to move when living in a deprived neighbourhood compared to living in non-deprived neighbourhood.

Statistical analysis

The repeated-measurement longitudinal data were analysed using multilevel regression where the repeated person-observations were nested within the individual participants. The total regression coefficient in multilevel regression model can be decomposed into (1) between-individuals regression representing how the outcome is related to exposure values averaged across all person-observations within individuals, and (2) within-individual regression representing how the outcome is related to variation in the exposure around the individual's mean level of the exposure across all person-observations.[16] These two components can be separated with the multilevel regression model of $y_{it} = \alpha + \beta_{0i} + \beta_W(x_{it} - \bar{x}_{i.}) + \beta_B\bar{x}_{i.} + \varepsilon_{it}$ where α is the overall intercept, β_{0i} is the individual-specific intercept, x_{it} is the exposure variable for the ith participant at the tth measurement time of the participant, $\bar{x}_{i.}$ is the mean value of the exposure variable averaged across all measurement times separately within each participant, and ε_{it} is the error term. The regression coefficient β_W gives the *within-individual* estimate and β_B gives the *between-individuals* estimate. The difference between these coefficients was tested using the Wald test.[17] All models were adjusted for sex, age and self-reported race/ethnicity (0=white, 1=other). Self-rated health and psychological distress were modelled with linear regression, the number of illnesses with Poisson regression, and neighbourhood dissatisfaction and preference to move with logistic regression. Preliminary analyses with categorical neighbourhood deprivation score (0–20, 20–40, 40–60 and above 60) suggested no major non-linear patterns with the outcomes (data not shown), so the main analyses were fitted with linear deprivation score.

Associations between health and subsequent residential moves to more compared to less deprived neighbourhoods were tested with logistic regressions among those for whom the level of neighbourhood deprivation changed between two consecutive follow-up

waves. Individuals who did not move between consecutive follow-up waves, or who moved across neighbourhoods with identical levels of deprivation, were excluded. The person-observations for this analysis consisted of 2-wave datacycles in which health at datacycle baseline was used to predict mobility between the datacycle and next study wave, and all the person-observations were pooled in a single data set (n=12 014 person-observations of 5869 persons). All health variables were assessed in separate models, adjusted for sex, age, study wave, race/ethnicity and neighbourhood deprivation at datacycle baseline.

Analyses were fitted using xtreg, xtlogit and xtpoisson packages of Stata V.13.1 statistical software. To take into account the non-independence of participants from the same families, SEs were calculated using robust estimator with family as the clustering variable in all analyses.

RESULTS

Of the 17 001 participants, 34.5% lived in at least two neighbourhoods (18.8% in two, 8.2% in three, 3.7% in four and 3.9% in five or more neighbourhoods) with different levels of deprivation during the follow-up period (n=5869 persons contributing 68 150 person-observations), and these participants provided data to estimate the within-individual associations (table 1). Intraclass correlation for neighbourhood deprivation was r=0.86, indicating stability in deprivation over time. Online supplementary table S1 shows levels of deprivation of the origin and destination neighbourhoods for all the moves—a substantial proportion of moves were across neighbourhoods with different levels of deprivation.

Neighbourhood deprivation was associated with poorer self-rated health, and higher psychological distress, number of health problems and physical limitations (figure 1; see online supplementary table S2). However, these associations were due to between-individuals differences; the associations were not observed in within-individual analyses of participants who moved across neighbourhoods with different levels of deprivation. Individuals living in deprived neighbourhoods were more likely to be dissatisfied with their neighbourhood and more likely to prefer to move (figure 1). These associations were stronger in the within-individual regressions compared to between-individuals regressions, indicating that the method could detect within-individual variation where it was expected.

Sensitivity analysis

Neighbourhood effects may require long exposure periods, so the above models were rerun by including only person-observations of participants who had lived in the same neighbourhood for at least three consecutive years, excluding the 1-year and 2-year person-observations. This did not change the main results (see online supplementary table S3), and increasing the inclusion criteria to 5 years of stable residence did not alter the conclusions (see online supplementary table S4). Similarly, duration of residence in the neighbourhood did not moderate the within-individual associations on health outcomes, suggesting no cumulative effects with longer residence times (data not shown). Adjusting for time-varying indicators of income, education, employment status and marital status attenuated the between-individuals associations but did not change the within-individual associations (see online supplementary table S5).

While the participants' residential locations were assessed at each study wave, neighbourhood data were based on the 2004 Multiple Deprivation Index, for which most of the data were derived from year 2001. The deprivation scores might therefore become increasingly inaccurate as the time from year 2001 increases. Restricting the follow-up period to a 9-year period between 1997 and 2005 did not alter the main results substantially (see online supplementary table S6). Finally, the results for Scotland and Wales were very similar to the results for England presented above (see online supplementary tables S7 and S8).

Selective residential mobility

Among movers, poor self-rated health, psychological distress, higher number of diseases, neuropsychiatric illnesses and functional limitations were associated with higher odds of moving to a more compared to less deprived neighbourhoods (table 2), suggesting that poorer health was associated with higher probability of moving to more deprived neighbourhoods among those who moved. These associations remained the same or strengthened when only moves across neighbourhoods with more than a five deprivation-score difference were included in the analysis (see online supplementary table S9).

DISCUSSION

Individuals who live in deprived neighbourhoods of Great Britain have poorer health than those who live in more

Table 1 Descriptive characteristics of the England sample of the British Household Panel Survey 1991–2009, including only individuals who moved at least once

	Mean (SD)	SD (between)*	SD (within)*	Per cent (n)†
Age	39.5 (16.4)	16.3	4.5	
Multiple deprivation index	20.4 (15.3)	13.3	7.8	
Poor self-rated health	2.15 (0.92)	0.68	0.64	
GHQ score	11.2 (5.54)	3.74	4.26	
Number of health problems	0.95 (1.19)	0.97	0.70	
Cardiometabolic illnesses	0.17 (0.44)	0.38	0.22	
Neuropsychiatric illnesses	0.17 (0.43)	0.32	0.29	
Functional limitations	0.19 (0.60)	0.54	0.32	
Sex (% female)				53.4 (36 616)
Race (% non-white)				6.3 (4332)
Dislikes neighbourhood (%)				9.2 (6258)
Wants to move (%)				39.8 (26 903)

*SDs calculated separately for between-individuals and within-individual sources of variation.
†Percentages and numbers calculated based on person-observations. Total n=68 510 person-observations of 5869 persons, except for cardiometabolic illnesses (30 491 observations of 4942 persons), functional limitations (36 013 observations of 5349 persons), dislike of neighbourhood (67 999 observations of 5869 persons) and wanting to move (67 594 observations of 5869 persons).
GHQ, General Health Questionnaire.

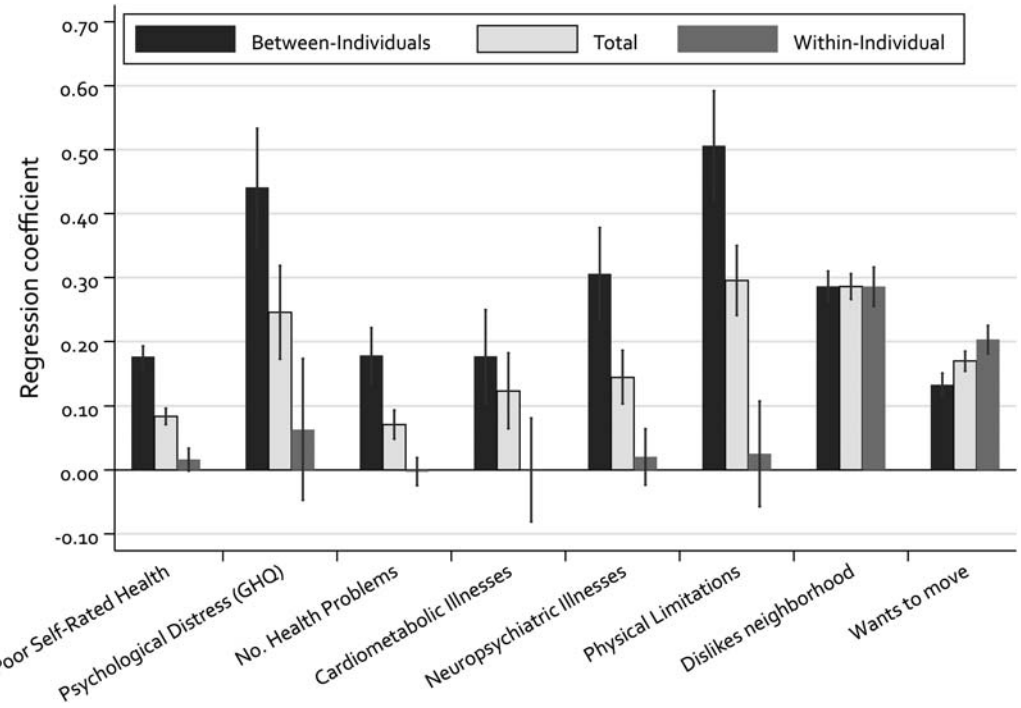

Figure 1 Associations between neighbourhood deprivation and health outcomes for between-individuals, total and within-individual regressions. Bars represent the magnitude of linear regression coefficients per 20 units of multiple deprivation index (for self-reported health and psychological distress), logged Poisson regression coefficients per 20 units of multiple deprivation index (for the count variables of illnesses), and logit ORs per 5 units of multiple deprivation index (for disliking the neighbourhood and wanting to move). Error bars are 95% CIs. N=up to 137 884 person-observations from 17 001 unique individuals between years 1991 and 2009. See online supplementary table S2 for numerical details.

advantaged neighbourhoods. However, these associations were absent when comparing the same individuals who lived in different neighbourhoods over time. That is, an individual living in a deprived neighbourhood did not have poorer health compared to another time when the same individual was living in a less deprivedneighbourhood. The discrepancy of the within-individual and between-individuals regressions was observed in subsamples from England, Scotland and Wales, and across multiple outcomes of physical and mental health. These findings lend no support for the hypothesis that neighbourhood deprivation causes poorer health. It seems more likely that the presumed 'neighbourhood effects' are the 'neighbourhood consequences' of the more fundamental social inequalities that determine people's health and their opportunities to move to desired residential areas.

Table 2 Associations between health and moving to more compared to less deprived neighbourhood among movers

	OR (95% CI)	Number of person-observations (persons)
Poor self-rated health (score <4)	1.34 (1.23 to 1.47)	12 014 (5869)
Psychological distress (GHQ >1)	1.18 (1.08 to 1.28)	12 014 (5869)
Number of health problems (>1 problems)	1.27 (1.15 to 1.40)	12 014 (5869)
Cardiometabolic illnesses (>0 problems)	1.19 (0.93 to 1.52)	4266 (2731)
Neuropsychiatric illnesses (>0 problems)	1.25 (1.12 to 1.40)	12 014 (5869)
Functional limitations (>0 limitations)	1.40 (1.15 to 1.71)	7238 (4273)
Dislikes neighbourhood (yes)	0.98 (0.87 to 1.10)	11 917 (5846)
Wants to move (yes)	0.81 (0.74 to 0.88)	11 833 (5820)

Values are ORs and 95% CIs for moving to more (compared to less) deprived neighbourhood associated with dichotomously coded variables. Each variable was assessed in a separate logistic regression model, adjusted for age, sex, study wave and baseline neighbourhood deprivation. Person-observations consist of two consecutive study waves where datacycle's baseline variables are used to predict odds of moving to more deprived neighbourhood than their baseline neighbourhood between the study waves among participants who moved across neighbourhoods (0=moves to less deprived neighbourhood than the person's baseline neighbourhood, 1=moves to more deprived neighbourhood than the person's baseline neighbourhood). Individuals who did not move were excluded from this analysis.
GHQ, General Health Questionnaire.

The present study benefits from many methodological strengths, including the use of repeat-measures data to separate within-individual versus between-individuals associations; up to 18 annual measurements of neighbourhood residence and health outcomes; large population-based sample; well-established measure of neighbourhood deprivation; detailed geographical recording of participants' residence at the level of lower super output areas; and the inclusion of two comparison outcomes that demonstrated the validity of the within-individual regression in the present context. The main limitation was the use of self-reported health measures only. Also, neighbourhood deprivation score was assigned to each residential location based on the 2001 deprivation data. This introduced measurement imprecision in the deprivation indicator over the follow-up period, and it was not possible to examine whether neighbourhoods that became less or more deprived over time might have affected the residents of those neighbourhoods. The analysis was also limited by the restricted range of within-individual variation in neighbourhood deprivation.

Longitudinal studies,[1 2] multilevel studies[18 19] and social experiments[20] are often cited as evidence for causality of neighbourhood effects. However, longitudinal studies with only one

baseline neighbourhood measurement are subject to confounding, as age-related health trajectories may reflect stable individual characteristics,[21–23] depending on the health measure.[24 25] Multilevel studies may be biased by residual confounding due to incomplete adjustment of relevant individual confounders,[11 14 15 26] and the results from social experiments may not be generalisable to neighbourhood effects in the general population. The current results of non-causal neighbourhood effects are in agreement with the 10-year Australian study, which observed very few within-individual associations between neighbourhood socioeconomic disadvantage and individual health outcomes.[15] Thus, the conclusions of the Australian study can be generalised to Great Britain.

Among participants who moved between neighbourhoods, individuals with poorer physical and mental health were more likely to move to more deprived neighbourhoods. This suggests that selective residential mobility might contribute to associations between individual health and neighbourhood deprivation reported in cross-sectional studies.[1–6] Similar health-related associations with social selection were reported in the Australian study cited above,[15] and other studies have also found tentative evidence for similar social selection.[27–29] The present analysis examined only moves to more or less deprived areas, and did not attempt to estimate overall selective migration rates and how much these migration flows contribute to neighbourhood differences. Also, the present analysis did not attempt to determine whether health is associated with selective mobility independently of socioeconomic status and other social risk factors, or whether health is related to selective mobility because it is correlated with social risk factors that influence residential mobility. More detailed simulation models taking into account overall migration rates between neighbourhoods are needed to assess how much social selection might create neighbourhood variation in health.

Within-individual analysis represents a methodological improvement over cross-sectional studies, but it cannot identify all the potential causal processes of neighbourhood health effects. First, neighbourhood deprivation may cause poorer health and risky health behaviours in childhood and adolescence,[30 31] and these effects may be carried into adulthood.[32 33] If the origins of neighbourhood effects can be traced to early 'critical periods' one would not expect to find within-individual effects in adulthood.[34–36] Second, the neighbourhood effects might take several years—maybe decades—to materialise, and the current follow-up time might have been too short to detect such long-term effects. However, there was no evidence of an increasing dose–response pattern over 3 or 5 years, so it seems unlikely that a dose–response pattern would emerge abruptly with longer time periods. Third, the present study only examined social and economic deprivation, and did not address the causal effects of specific environmental exposures, such as noise,[37] electromagnetic fields[38] or lack of greenspaces.[9] Fourth, this study did not examine whether some individuals are more vulnerable than others to potential causal neighbourhood effects.[4 39 40] Fifth, moving may be socially and psychologically disruptive in itself, which might confound the possible mental health benefits of moving to less deprived areas. Finally, the identification of causal neighbourhood effects may depend on various methodological factors, such as the geographical definitions of neighbourhoods, the measurement of relevant neighbourhood characteristics and health outcomes, as well as differences between countries and regions.[2]

In conclusion, the present results from a within-individual analysis of repeated-measurement data provide no evidence for a causal association between neighbourhood deprivation and adult health. neighbourhood differences in health may partly reflect the effects of selective residential mobility across more and less deprived neighbourhoods, but this needs to be investigated with more detailed analysis than was possible here. The findings emphasise the need for studies on the life-course patterns of neighbourhoods and health, and on the fundamental social inequalities that influence people's health and their opportunities to select desired neighbourhoods.

What is already known on this subject

- People living in socioeconomically deprived neighbourhoods have poorer health.
- It is unclear whether neighbourhood deprivation is a causal risk factor for poor health.

What this study adds

- This study examined whether changes in residential locations are associated with changes in health status.
- Although neighbourhood deprivation was associated with poor health, individuals did not have poorer health when they lived in a deprived neighbourhood compared to another time when they were living in a less deprived neighbourhood.
- These data suggest that neighbourhood deprivation is not a causal risk factor for poor health in adulthood.

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Competing interests None.

Patient consent Obtained.

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