Influence of Hospital Volume on Revision Rate After Total Knee Arthroplasty with Cement

Mona Badawy, MD, Birgitte Espehaug, PhD, Kari Indrekvam, MD, PhD, Lars B. Engesæter, MD, PhD, Leif I. Havelin, MD, PhD, and Ove Furnes, MD, PhD

Investigation performed at Kysthospital in Hagavik, Hagavik, and Norwegian Arthroplasty Register, Bergen, Norway

Background: The number of total knee replacements has substantially increased worldwide over the past ten years. Several studies have indicated a correlation between high hospital procedure volume and decreased morbidity and mortality following total knee arthroplasty. The purpose of the present study was to evaluate whether there is a correlation between procedure volume and the risk of revision following total knee arthroplasty with use of hospital volume data from the Norwegian Arthroplasty Register.

Methods: Thirty-seven thousand, three hundred and eighty-one total knee arthroplasties that were reported to the Norwegian Arthroplasty Register from 1994 to 2010 were used to examine the annual procedure volume per hospital. Hospital volume was divided into five categories according to the number of procedures performed annually: one to twenty-four (low volume), twenty-five to forty-nine (medium volume), fifty to ninety-nine (medium volume), 100 to 149 (high volume), and ≥150 (high volume). Cox regression (adjusted for age, sex, and diagnosis) was used to estimate the proportion of procedures without revision and the risk ratio (RR) of revision. Analyses were also performed for two commonly used prosthesis brands combined.

Results: The rate of prosthetic survival at ten years was 92.5% (95% confidence interval, 91.5 to 93.4) for hospitals with an annual volume of one to twenty-four procedures and 95.5% (95% confidence interval, 94.1 to 97.0) for hospitals with an annual volume of ≥150 procedures. We found a significantly lower risk of revision for hospitals with an annual volume of 100 to 149 procedures (relative risk = 0.73 [95% confidence interval, 0.56 to 0.96], p = 0.03) and ≥150 procedures (relative risk = 0.73 [95% confidence interval, 0.54 to 1.00], p = 0.05) compared with hospitals with an annual volume of one to twenty-four procedures. Similar results were found when we analyzed two commonly used prosthesis brands.

Conclusions: In the present study, there was a significantly higher rate of revision knee arthroplasties at low-volume hospitals as compared with high-volume hospitals.

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

Total knee arthroplasty is now a common and increasingly used surgical procedure that, in some countries, has bypassed total hip arthroplasty in terms of the number of procedures performed[1]. It is an established procedure with a high rate of patient satisfaction for the treatment of knee osteoarthritis[2]. There are multiple factors that may affect the outcome of total knee arthroplasty[3-5]. Patient characteristics and surgical indications, surgical technique, the quality of the implant and the bone cement, and implant-specific education are all factors that affect surgical quality. Hospital and surgeon volume are also considered to be important factors[6,7], but not all studies have demonstrated an association between surgeon volume and implant survival after total knee arthroplasty[8]. There have been reports of higher risks of perioperative and postoperative complications and higher rates of mortality following procedures performed at low-volume hospitals[9-11]. Some studies have shown a correlation between higher procedure volume and shorter length of hospital stay after total

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knee arthroplasty[12,13]. Others have shown that there is coherence between low volume and inferior functional outcome after total knee arthroplasty[14]. A higher short-term risk of complications after total knee arthroplasty has been associated with lower hospital and surgeon volumes, but very few studies have proven a relationship between procedure volume and implant survival. A study from the United States involving Medicare data suggested that procedures performed at low-volume hospitals are associated with a greater risk of revision at the time of intermediate-term follow-up (five and eight years)[8]. To our knowledge, there have been no studies involving national implant registry data that have investigated a possible correlation between hospital volumes and the rate of revision following total knee arthroplasty. Because of the large number of hospitals and procedures involved[15], the Norwegian Arthroplasty Register provides valuable and dependable measures that can used to analyze different volume-groups in order to evaluate the association between volume and the rate of revision.

The purpose of the present study was to evaluate whether there is a correlation between procedure volume and the risk of revision following total knee arthroplasty with use of hospital volume data from the Norwegian Arthroplasty Register.

Materials and Methods

The Norwegian Arthroplasty Register was established in 1987 and initially included only hip arthroplasties. In 1994, the register started to include knee arthroplasties. The Norwegian Arthroplasty Register includes 99% of primary knee arthroplasties and 97% of revisions when checked against the Norwegian Patient Register[15].

Hospital Volume

The Norwegian Arthroplasty Register contains data on 37,381 primary total knee arthroplasties that were performed during the time period from 1994 to 2010. Thirty-three thousand, three hundred and seventeen (89%) of these total knee arthroplasties were performed without a patellar component, and, among these, 84% were performed with cement. To examine the annual surgery volume per hospital, we analyzed registry data for total knee arthroplasty procedures that were performed with cement and without a patellar component from 1994 to 2010. We selected this implant group because cemented implants without a patellar component are preferred at the majority of hospitals in Norway. We excluded implant brands that are rarely used, such as posterior stabilized designs (1180 implants) and hinged prostheses (sixty-five implants). After these exclusions, a total of 26,698 total knee arthroplasty procedures were analyzed (Fig. 1).

Hospital volume was categorized into five volume-groups (one to twenty-four, twenty-five to forty-nine, fifty to ninety-nine, 100 to 149, and ≥150). These cut-points were based on the mean annual numbers of total hip arthroplasties for the years 1994 to 2010 as reported in other similar studies[9,16,17].

Because of the small number of revision arthroplasties, adjustment for prosthesis brand could not be done in the Cox model. We therefore performed a subanalysis on the AGC (Biomet, Warsaw, Indiana) and LCS (DePuy, Warsaw, Indiana) implants combined as these implants are commonly used and are well represented in all of the volume groups (with 1630 such implants in the one to twenty-four-procedure group, 2239 in the twenty-five to forty-nine-procedure group, 2250 in the fifty to ninety-nine-procedure group, 955 in the 100 to 149-procedure group, and 172 in the ≥150-procedure group).

Statistical Analysis

Descriptive analyses were used to assess patient characteristics for the different hospital and surgeon volume categories. Survival analyses were performed with revision of the prosthesis for any reason as the end point. Information on deaths and emigrations was retrieved from the National Population Register until December 31, 2010. The survival times of unrevised implants were censored at the date of death or emigration or at the last date of observation (December 31, 2010). Kaplan-Meier estimated survival curves were constructed for hospital volume categories, and the survival percentages at ten years are reported. To evaluate the effect of volume on prosthetic survival, we used the Cox regression model to calculate risk ratios (RR). These values are presented with 95% confidence intervals and p values relative to the lowest-volume group.

The Cox regression results regarding hospital volume were adjusted for age, sex, and diagnosis. Cox regression analyses with volume group as a stratification factor were used to construct adjusted survival curves. As many prosthesis brands had been used in small numbers and were associated with few revisions, adjustment for brand was not feasible in the Cox analyses. We therefore performed a subanalysis with the AGC and LCS implants combined.

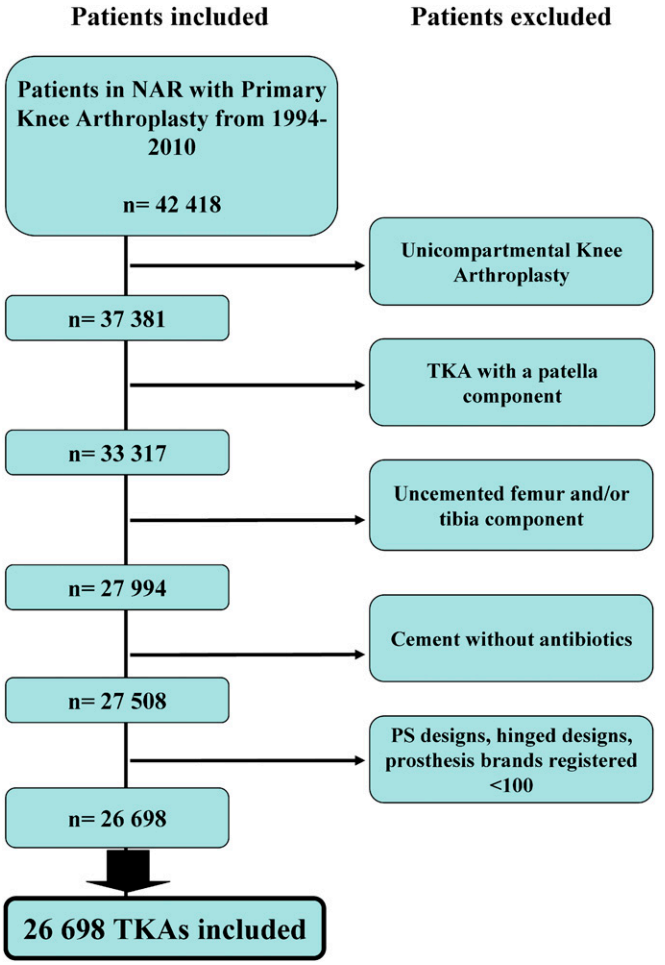

Fig. 1

Twenty-six thousand, six hundred and ninety-eight total knee arthroplasties (TKA) were selected for inclusion in this study. Knees that were treated with unicompartmental knee arthroplasty, uncemented total knee arthroplasty, total knee arthroplasty with a patellar component, cement without antibiotics, and uncommon designs and brands were excluded. NAR = National Arthroplasty Register, PS = posterior stabilized.

Source of Funding

There was no external funding source.

TABLE I Patient and Procedure Characteristics*

	Annual Hospital Volume				
	<25 Procedures	25 to 49 Procedures	50 to 99 Procedures	100 to 149 Procedures	≥150 Procedures
No. of procedures	4685	7497	10,551	2131	1834
Male sex *(%)*	29	31	33	37	32
Age† *(yr)*	72 (20 to 93)	72 (22 to 92)	71 (26 to 96)	71 (22 to 92)	70 (31 to 91)
Osteoarthritis *(%)*	81	85	88	90	87
Common implants† *(%)*					
Profix (7002 implants)	23	30	33	6	0
LCS Complete (5501 implants)	8	8	26	22	80
AGC (3759 implants)	20	15	11	15	8
LCS (3511 implants)	15	14	10	30	2
Genesis I (2049 implants)	12	15	3	0	0
Duracon (1945 implants)	6	7	7	19	0
Cement with antibiotics *(%)*	96	98	99	100	100

*Patient and procedure characteristics for 26,698 total knee arthroplasties performed with cement and without patellar resurfacing from 1994 to 2010 in Norway for five different hospital volume categories. †The values are given as the median, with the range in parentheses. ‡The values are expressed as the percentage of implants in each volume group. The most commonly used implants are shown. (A total of twenty-three different implant brands were registered in the Norwegian Arthroplasty Register. The six brands listed above constituted 89% of the total number of implants.)

Results

The registration form in the Norwegian Arthroplasty Register includes information on patient characteristics, diagnosis, previous surgery on the knee, implant brand and type, fixation method, and other relevant data. Revision was defined as partial or complete removal or exchange of one or more implant components and was linked to the primary surgical procedure by the unique national identification number of the patient.

The patient and procedure characteristics according to hospital volume are shown in Table I.

Hospital Volume

The hospitals with an annual volume of one to twenty-four procedures accounted for 4685 implants (17.5%), those with an annual volume of twenty-five to forty-nine procedures accounted for 7497 implants (28.1%), those with an annual volume of fifty to ninety-nine procedures accounted for 10,551 implants (39.5%), those with an annual volume of 100 to 149 procedures accounted for 2131 implants (8.0%), and those with an annual volume of ≥150 procedures accounted for 1834 implants (6.9%). The higher-volume group did not have the highest number of patients because higher-volume hospitals were uncommon during the first years of registration (Fig. 2).

The majority of hospitals had a gradual increase in annual hospital volume over time, but a few hospitals continued to be low-volume units and some stopped performing this procedure.

The percentage of hospitals performing fewer than twenty-five total knee arthroplasties per year decreased, and the percentage of hospitals performing ≥100 total knee arthroplasties per year increased. In 1995, 88% of the hospitals performed fewer than fifty procedures annually. In 2010, 84% of the hospitals performed at least fifty procedures annually (Fig. 2).

The rate of prosthetic survival at ten years was 92.5% (95% confidence interval [CI], 91.5 to 93.4) for hospitals with an annual volume of one to twenty-four procedures and 95.5% (95% CI, 94.1 to 97.0) for hospitals with an annual volume of ≥150 procedures (Table II).

The risk of revision was assessed in comparison with the results for the low-volume hospitals (one to twenty-four procedures annually). Compared with knees that had been treated at hospitals with an annual volume of one to twenty-four procedures, those that had been treated at hospitals with an annual volume of twenty-five to forty-nine and fifty to ninety-nine procedures had lower risks of revision, but the differences

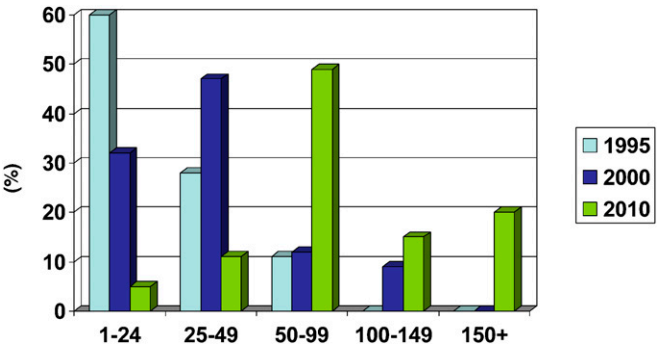

Fig. 2

Bar graph showing the change in hospital volumes over time, with the three columns indicating the years of 1995, 2000, and 2010.

TABLE II Cox Regression Analysis

Annual Hospital Volume	No. of Total Knee Arthroplasties	No. of Revisions	Kaplan-Meier Estimated Cumulative Survival Rate at 10 Years* *(%)*	Adjusted RR*†	P Value
<25 procedures	4685	280	92.5 (91.5 to 93.4)	1	
25 to 49 procedures	7497	373	93.1 (92.3 to 93.9)	0.94 (0.80 to 1.09)	0.40
50 to 99 procedures	10551	405	93.0 (92.0 to 94.0)	0.93 (0.80 to 1.08)	0.35
100 to 149 procedures	2131	64	94.7 (93.0 to 96.3)	0.73 (0.56 to 0.96)	0.03
≥150 procedures	1834	47	95.5 (94.1 to 97.0)†	0.73 (0.54 to 1.00)	0.05

*The 95% CI is given in parentheses. †Estimated risk ratio with adjustment for age, sex, and diagnosis. ‡Estimated survival at five years (last revision).

were not significant (RR = 0.94 [95% CI, 0.80 to 1.09], p = 0.40 and RR = 0.93 [95% CI, 0.80 to 1.09], p = 0.35, respectively). There was a significant difference between the hospitals with an annual volume of 100 to 149 procedures and the low-volume units (RR = 0.73 [95% CI, 0.56 to 0.96], p = 0.03). The hospitals with an annual volume of ≥150 procedures had the lowest risk of revision compared with the other groups (RR = 0.73 [95% CI, 0.54 to 1.00], p = 0.05) (Table II). These numbers indicate an influence of hospital volume on the risk of revision in favor of the high-volume hospitals (Fig. 3).

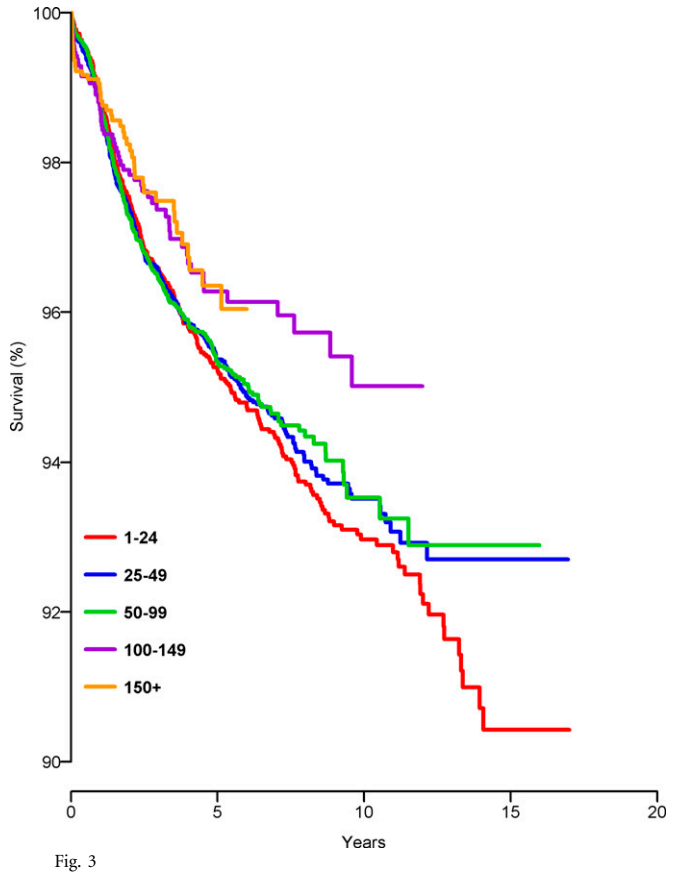

Fig. 3

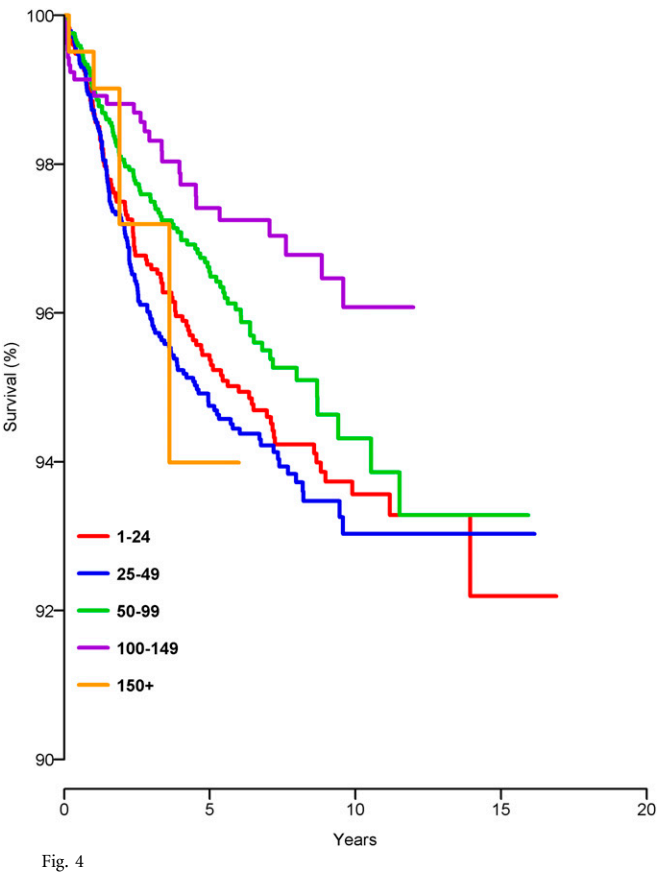

Fig. 4

Fig. 3 Kaplan-Meier survival curves for total knee arthroplasties performed with cement and without patellar resurfacing in Norway from 1994 to 2010, with revision for any reason as the end point. The results of Cox regression analysis were adjusted for age, sex, and diagnosis. The results are shown for the five different hospital volume groups described in the text. **Fig. 4** Kaplan-Meier survival curves for total knee arthroplasties performed with cemented AGC and LCS implants without patellar resurfacing from 1994 to 2010, with revision for any reason as the end point. The results of Cox regression analysis were adjusted for age, sex, and diagnosis. The results are shown for the five different hospital volume groups described in the text.

In the subanalysis of AGC and LCS implants, we observed similar and corresponding results. Compared with knees that had been treated at hospitals with an annual volume of one to twenty-four procedures, those that had been treated at hospitals with an annual volume of twenty-five to forty-nine and fifty to ninety-nine procedures had lower risks of revision, but the differences were not significant (RR = 1.10 [p = 0.49] and RR = 0.82 [p = 0.17], respectively). A significant difference was found between the hospitals with an annual volume of 100 to 149 procedures and the low-volume hospitals (RR = 0.56; p = 0.007). The hospitals with an annual volume of ≥150 procedures had a low number of procedures and revisions compared with the other volume groups for these specific implant brands and did not have significant improvements regarding the risk of revision (RR = 0.81; p = 0.68) (Fig. 4).

Discussion

This register-based study indicates that there was significantly better prosthetic survival following procedures performed at higher-volume hospitals as compared with low-volume hospitals during 1994 to 2010. However, these results might be influenced by several other factors[18,19].

To study the influence of annual hospital volume on prosthetic survival, we used registry data from the Norwegian Arthroplasty Register to estimate the proportions of procedures without revision and relative differences in the risk of revision. Although the registry data do not include functional outcome after this procedure, the revision rate is an important measure of the clinical outcome of total knee arthroplasty.

Comparison with Relevant Studies

The implants that were used in the later years may have been of better quality, and the surgical technique has improved, as has been shown for total hip arthroplasties with cement[20]. Styron et al. demonstrated that the annual volume of total knee arthroplasty procedures performed by the surgeon and hospital had a greater impact on the length of hospital stay than patient-related characteristics did[13]. The gradual improvement of the survival curve following total knee arthroplasty might be multifactorial, but the impact of volume probably is a crucial contributor. The benefits of high volume probably include not only improved surgical technique but also a better understanding of the importance of patient selection and the indications for surgery.

A higher short-term risk of complications such as wound infection after total knee arthroplasty has been associated with lower hospital and surgeon volume[21]. There also have been reports of higher risks of perioperative and postoperative complications and adverse outcomes (including pneumonia, acute myocardial infarction, pulmonary embolus, and deep infection) and higher rates of mortality in low-volume hospitals[9-11]. Other reports have indicated that there is coherence between low volume and inferior functional outcome following total knee arthroplasty[14]. Widespread differences have been reported in hospital volume definitions, with between two and five hospital volume categories being used. The volume groups also differ in size. These discrepancies limit the conclusiveness of results[16].

Strengths and Limitations

Arthroplasty registers offer the ability to analyze outcome and to provide early warnings of failing implants and methods[22]. Except for revision, the Norwegian Arthroplasty Register does not include any clinical outcome data, which is considered a disadvantage. However, the Norwegian Arthroplasty Register has registered knee arthroplasties since 1994 and provides reliable measures of the change in volume over time. We therefore consider the results for hospital volume to be accurate. However, we are aware of other relevant factors contributing to the improving results in total knee arthroplasty, such as improvements in surgical and cementing techniques, implants, and implant-specific education.

We did not adjust for prosthesis brand when analyzing hospital volume, which might be considered to be a weakness. However, we compensated for this by performing a separate analysis of two commonly used brands that were well represented in all volume categories and achieved corresponding results. A recent study from the Norwegian Arthroplasty Register evaluated the different knee prosthesis brands and demonstrated that the implant most commonly used in the high-volume centers (Table I) had an average result when compared with the other implant brands and was not among the implants with the lowest risk of revision[23].

Explanations and Mechanisms

Standardization of procedure and care is important[4] and is well established in our country as nearly all procedures involve the use of cemented implants, antibiotics in the cement, perioperative antibiotic prophylaxis, antithrombosis prophylaxis, and some kind of rehabilitation after surgery. All resident orthopaedic surgeons in Norway are required to complete a practical and theoretical prosthesis course, and a textbook has been written for this course[24]. Patient selection and indications also play an important role in the outcome of total knee arthroplasty. Survival curves from the different national arthroplasty registers show a gradual improvement over time from 1994 to 2010 for the results of total knee arthroplasty[25,26]. Some of this effect might be volume-related.

In conclusion, in the present study, we found a significantly higher rate of revision following knee arthroplasties performed in low-volume hospitals as compared with high-volume hospitals. ■

Mona Badawy, MD
Kari Indrekvam, MD, PhD
Kysthospital in Hagavik,
Hagaviksbakken 25, 5217 Hagavik, Norway.
E-mail address for M. Badawy: mona.badawy@helse-bergen.no.
E-mail address for K. Indrekvam: kari.indrekvam@helse-bergen.no

Birgitte Espehaug, PhD
Leif I. Havelin, MD, PhD
Ove Furnes, MD, PhD
The Norwegian Arthroplasty Register,
Department of Orthopaedic Surgery,
Haukeland University Hospital, 5021 Bergen, Norway.
E-mail address for B. Espehaug: birgitte.espehaug@helse-bergen.no.
E-mail address for L.I. Havelin: leif.havelin@helse-bergen.no.
E-mail address for O. Furnes: ove.furnes@helse-bergen.no

Lars B. Engesæter, MD, PhD
Department of Clinical Medicine,
University of Bergen, 5021 Bergen, Norway.
E-mail address: lars.engeseter@UiB.no

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