Received: 26 June 2022 | Revised: 31 October 2022 | Accepted: 1 November 2022

DOI: 10.1111/jep.13791

ORIGINAL PAPER

Journal of Evaluation in Clinical Practice
International Journal of Public Health Policy and Health Services Research
WILEY

Increased magnetic resonance imaging in prostate cancer management—What are the outcomes?

Bjørn Hofmann[1,2] | Erik Skaaheim Haug[3,4,5] | Eivind Richter Andersen[1] | Elin Kjelle[1]

[1]Department of Health Sciences, Norwegian University of Science and Technology, Gjovik, Norway

[2]Centre for Medical Ethics, University of Oslo, Oslo, Norway

[3]Department of Urology, Vestfold Hospital Trust, Tønsberg, Norway

[4]Institute of Cancer Genomics and Informatics, Oslo University Hospital, Oslo, Norway

[5]Norwegian Cancer Registry, Oslo, Norway

Correspondence

Bjørn Hofmann, Department of Health Scienc, Norwegian University of Science and Technology, Gjøvik, PO box 191, N-2801 Gjøvik, Norway.
Email: bjoern.hofmann@ntnu.no

Funding information

Norges Forskningsråd

Abstract

Rationale: Increased attention to cancer care has instigated altered systems for screening, diagnosis, and management of various types of cancer, such as in the prostate. While such systems very likely have improved the quality of cancer care, they also result in the altered use of specific services, such as magnetic resonance imaging (MRI).

Aims and Objective: To study the change in the use of prostate MRI in the Norwegian health care system from 2013 to 2021 and to investigate some reasons for and potential implications of this change.

Method: Data from the Norwegian Health Economics Administration (HELFO), The Cancer Registry of Norway and Cause-of-death registry at the Norwegian Institute of public health and the health registry of Vestfold Hospital Trust were used for descriptive statistical analysis.

Results: The number of MRIs of the prostate increased threefold from 2013 to 2021, representing an extra cost of 2 million USD in 2020. The incidence of prostate cancer was stable at about 5000 cases per year, corresponding to 178 per 100,000 men, indicating no increased overdiagnosis. However, the clinical staging has changed substantially during this period, indicating stage and grade migration. The number of negative biopsies was reduced, and there are three MRIs per reduced negative biopsy. The number of persons on active surveillance increased during the period. However, these changes are partly independent of the increase in the number of MRIs.

Conclusion: There was a substantial increase in the number of prostate MRIs and thus an increase in costs. This appears to have contributed to the reduction of negative biopsies, improved staging and increased active surveillance. However, as these effects are partly independent of the increase in MRIs, we need to document the outcomes for patients from prostate MRIs as their opportunity costs are substantial.

KEYWORDS

evaluation, health services research, practical reasoning

Abbreviations: AS, active surveillance; MRI, magnetic resonance imaging; M+, incidence of metastatic cancers; NOK, Norwegian Kroner; N+, cancers with positive regional lymph nodules; PCa, prostate cancer.

1 | INTRODUCTION

Prostate cancer (PCa) is the second most frequent diagnosed cancer among men worldwide, and it is the sixth leading cause of cancer death in men.[1] However, a large proportion of PCa is indolent and does not lead to any experienced symptoms, disease, or death if undetected, and the median age by death of PCa in Norway is 83 years.[2] Low-risk cases can after careful consideration be managed through active surveillance (AS).[3] Clinically significant cancers on the other hand need to be treated to avoid metastasis and PCa-related deaths.[3] In Norway, about 5000 men are diagnosed with PCa each year and the number of new cases has been stable the last decade.[4] Likewise, the mortality rate is stable on about 1000 PCa-related deaths each year.[5]

Blood tests on prostate-specific antigen (PSA) are the main entrance test for subsequent diagnostic procedures. It has been estimated that between 2.3% and 15.4% of patients diagnosed via PSA are overdiagnosed, harbouring a clinically insignificant cancer.[6] The best imaging procedure to locate and stage PCa tumours is bi- or multiparametric magnetic resonance imaging (b/mpMRI),[7,8] which is thought to avoid unnecessary and potentially harmful biopsies.[9] However, due to the poor accuracy of PSA, b/mpMRI yields many suspicious findings calling for further investigations.[3,10–12] A prostate biopsy is necessary to establish the diagnosis.[3,10–12] Hence, many elevated PSA tests not due to PCa may lead to unnecessary b/mpMRIs with false-positive results, resulting in unnecessary biopsies.[13,14] Further, the indolent nature of many PCas makes practices with PSA, MRI and biopsies lead to the unnecessary diagnosis of clinically insignificant tumours and apparent reduction of mortality rates due to the treatment of many milder cases.[15]

AS has helped reduce the overtreatment of PCa, but over-diagnosis is still a problem[16–18] and may be enhanced by stage and grade migration.[19] Patients may be under AS for many years, living with the diagnosis of PCa for a long time, with a potential negative impact on their lives.[20] Interestingly, there has been a substantial increase of low-risk PCas on AS in Norway, from about 20% in 2009 to about 80% in 2018.[4] Thus, AS has the potential to be a high-volume driver for MRI utilisation when used for follow-ups.

In 2015, after early adoption in some hospitals, the Norwegian government introduced a fast-track system (pathway) to secure fast diagnosis and startup of treatment without unnecessary delays. This change may have caused an increased focus on PCa diagnosis and a change in the utilisation of MRI in the prostate.

MRI is a key instrument in (a) diagnosis of PCa, (b) staging of PCa and (c) AS. As MRIs in PCa are quite resource-intensive, can lead to overdiagnosis, distress and anxiety for the patient and result in increased opportunity costs, it is crucial to evaluate the use. Furthermore, several factors can have influenced the use of prostate MRIs, such as increased access to MRI, implementation of a fast-track system for diagnosis and possible changes in the management and follow-ups for PCa, such as in AS. Correspondingly, the changed use of MRIs may have resulted in a changed incidence of PCa, staging of PCa and the number of biopsies. Therefore, *the objective of this article is to study the change in the use of prostate MRI in the Norwegian health care system from 2013 to 2021 and to investigate potential reasons for and implications of this change*. Accordingly, we address the following research questions:

1. How has the number of MRIs of the prostate changed in Norway from 2013 to 2021?
2. How has the number of new cases of PCa per year changed during this period?
3. How has the clinical staging of PCas changed?
4. How have the numbers of negative biopsies and the number of persons on AS changed during this period?

2 | METHODS

The total number of out-patient prostate MRI examinations and the economic reimbursement registered at the Norwegian Health Economics Administration (HELFO) for the period 2013–2021 were retrieved in terms of codes in the Norwegian Classification of Radiological Procedures (NCRP) (i.e., codes SKE0AG and KE0AG) and costs (in NOK). The data included outpatient examinations performed at public hospitals and private institutions, but not in-patient examinations or examinations paid out-of-pocket.

Data on the incidence of PCa were retrieved from The Cancer Registry of Norway's online statistics (https://sb.kreftregisteret.no/insidens/, 14 June 2022).[4,21]

Data on mortality was retrieved from the cause-of-death registry at the Norwegian Institute of public health (NPI, http://statistikkbank.fhi.no/dar/, 14 June 2022).[5]

As national data on biopsies are not available, we analysed data from Vestfold Hospital Trust which covers 5% of the Norwegian population and fairly represents the Norwegian population (age, gender, rural/urban). To directly compare the biopsy data from Vestfold, we also included MRI data from Vestfold Hospital Trust.

Simple descriptive statistical analyses were performed in Microsoft Excel 2016.[22] A Pearson correlation was used to determine the relation between the number of MRIs of the prostate and the number of persons included in the fast-track pathway, persons diagnosed with PCa, under AS and the number of negative biopsies.

Costs were calculated as the sum of three sources: (1) reimbursement (HELFO); (2) copay (user fee, data retrieved from www.helsenorge.no) + (3) lump sum (40% of total, according to the Directorate of Health in Norway).

3 | RESULTS

3.1 | Change in number of MRIs (Q1)

The number of MRIs of the prostate has more than tripled in Norway from 2013 to 2021 (Figure 1). The costs for prostate MRIs

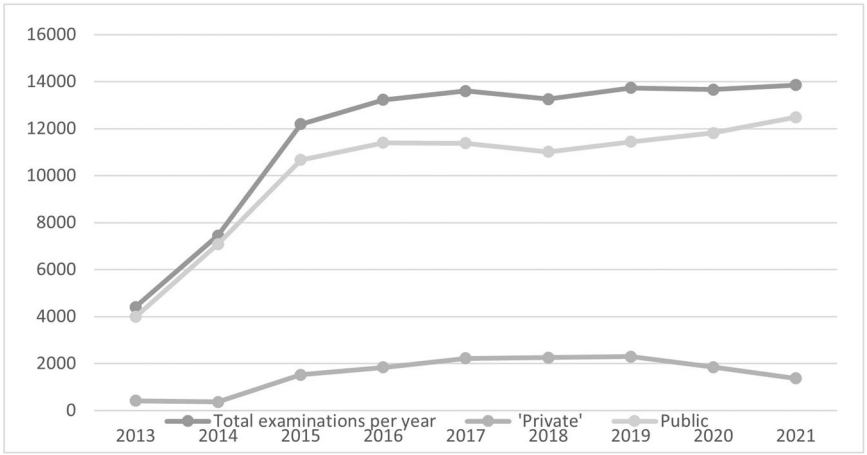

FIGURE 1 Number of MRI of the prostate in Norway 2013–2021 with details for where they are performed. 'Public' means public hospitals or radiological departments. 'Private' means privately run imaging centres that are commissioned by the public health care system for these examinations. As they, therefore, are not 'private' in the ordinary sense, they are marked with 'Private'.

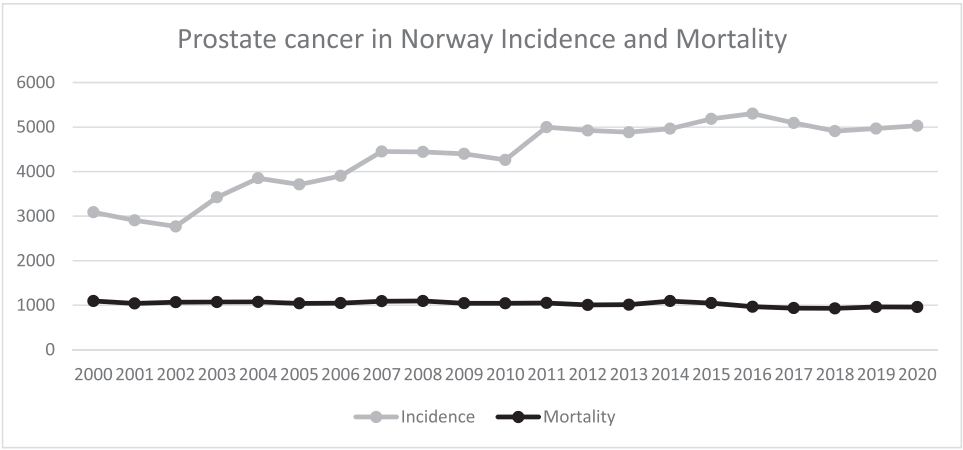

FIGURE 2 Incidence and mortality of prostate cancer in Norway 2000–2020

quadrupled from 2013 to 2020 and amounted to 2.77 million USD in 2020, 2.03 million USD more than in 2013.

These results raise the question of whether the increased number of MRIs can have influenced the incidence or staging of PCa.

3.2 | Incidence and staging of PCa from 2013 to 2020 (Q2 + Q3)

The incidence of PCa increased slightly after the introduction of the fast-track system in 2015 and decreased back to its previous level after 2018 as shown in Figure 2. The incidence of PCa has been stable at about 5000 cases per year, corresponding to 178 per 100,000 men since 2011. As expected, the mortality rate was stable during the study period, and there was an 8.8% reduction in the average number of PCa deaths for 2015–2020 compared to 2000–2014.

Investigating the change in cancer classification, we found that the distribution between cancers classified as localized, regional and metastatic was as shown in Figure 3. The results do not indicate any relationship between the number of MRIs and the classification.

Scrutinising the influence of the introduction of the fast-track system, we found the number of persons included in the fast-track pathway for PCa in Norway, as shown in Figure 4. There was a strong correlation between the number of MRIs and persons included in the fast-track pathway between 2015 and 2021 ($r = 0.82$, $p = 0.024$). There also was a strong correlation between MRIs and the number of persons under AS ($r = 0.76$, $p = 0.049$). As can be seen from Figure 4, the increase in MRIs started before the fast-track pathway.

To investigate how the increase in MRIs is distributed amongst the various institutions, we analysed the geographical variations in the number of MRIs performed. Figure 5 illustrates a fairly evenly increase in the distribution amongst the various radiological departments. However, as some of the public health care departments were overwhelmed by prostate MRIs in the fast-track system, MRIs were outsourced to private institutes (commissioned by the public health care system, thus denoted 'private').

4 | NUMBER OF NEGATIVE BIOPSIES AND NONREPRESENTATIVE BIOPSIES (Q4)

To assess whether the increasing number of MRIs changed biopsy practice, we applied data from Vestfold Hospital Trust. The number of negative biopsies decreased steadily from 2010 to 2020. There was, however, an increase in the number of biopsies taken after the diagnosis of PCa was registered from 2013 to 2017, before declining. The number of biopsies before the diagnosis of PCa decreased from 2016 (see Figure 6).

The number of negative biopsies was reduced by 46.2% from the period from 2010 to 2014 and to the period from 2016 to 2020. The total number of biopsies was reduced by 35% from 2016 to 2020 and the number of biopsies for diagnosis per new diagnosed cancer was reduced from around 2 (2010–2014) to around 1.7 (2017–2020), which is 15% reduction. The total number of biopsies per diagnosed cancer was reduced by 4.7% for the same period (see Figure 7).

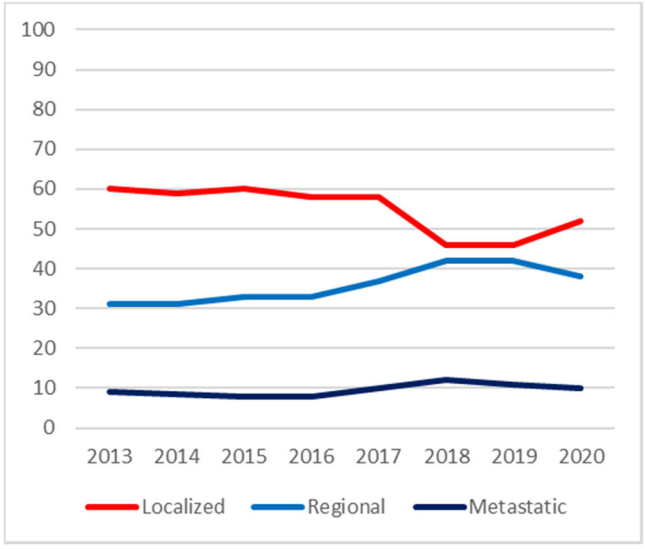

FIGURE 3 The proportion in percent of prostate cancers classified as localized, regional and metastatic from 2013 to 2020

Hence, the increased number of MRIs can have contributed to the reduction of negative biopsies.

Moreover, the number of MRIs per new PCa diagnosis increased from 1.61 to 4.94 from 2010 to 2020 (206.8% increase) and the number of MRIs per biopsy increased from 0.66 in 2010 to 1.1 in 2019 (66.7% increase). There was a weak negative correlation between the number of MRIs and the number of negative biopsies ($r = -0.30$).

As the increased use of MRI can also change its use for detection, staging, or AS, we investigated the data on MRIs at Vestfold hospital trust, which is shown in Figure 8. While the number of MRIs for staging did not change much from 2010 to 2020, MRIs for detection and for AS increased with 121.8% and 900%, respectively.

5 | DISCUSSION

The results show that the number of MRIs of the prostate has increased substantially in Norway from 2010 to 2021 (Q1). The incidence of metastatic PCa (Q2) has decreased, probably partly due to the dilution of more cases and early diagnosis. The number of local advanced PCa, for example, non-organ confined (cT3) tumours or regional lymph node positive disease (cN +), has increased (Q3). This is probably due to better staging with MRI, as earlier imaging was insensitive for these stages and was accordingly staged as a localized disease.

The number of negative biopsies decreased by 46.2%, while the total number of biopsies decreased by 15% in one hospital trust (Vestfold). However, the corresponding number of MRIs doubled (99% increase) during the same period (Q4). The number of MRIs per biopsy quadrupled, both because the number of biopsies has dropped, but also due to increasing use of MRI as part of AS and staging.

Prostate biopsies are related to infectious complications, and alternatives for the detection and surveillance of PCa have been welcomed. As biopsies may be abandoned in some patients with negative MRI and may be replaced in AS by surveillance MRI,[23] the

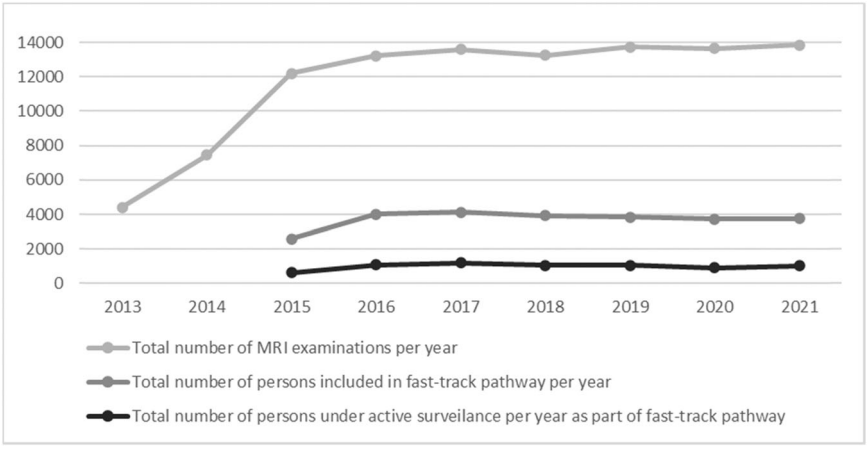

FIGURE 4 Total magnetic resonance imaging examinations of the prostate and the number of persons included in fast-track pathway for prostate cancer as well as the number of persons in active surveillance in this programme from 2013 to 2020.

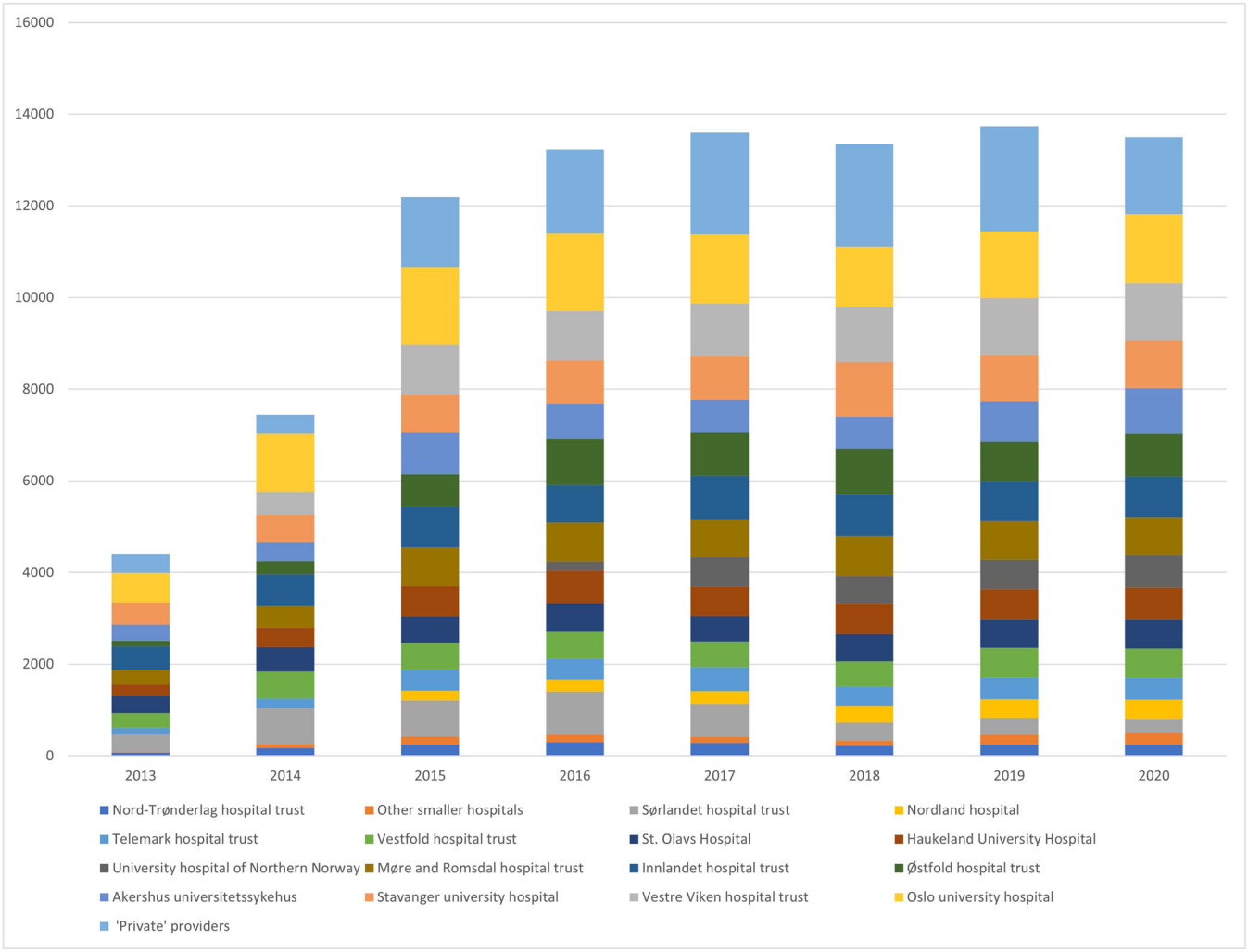

FIGURE 5 Number of MRI examinations per hospital and 'private' provider from 2013 to 2020

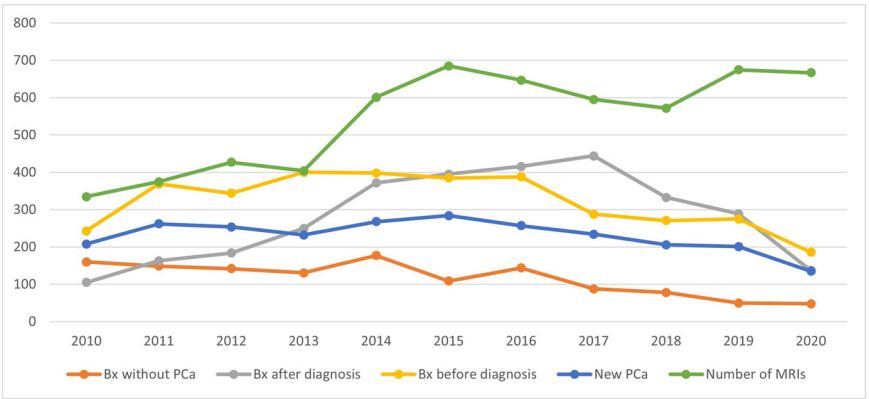

FIGURE 6 Number of biopsies and MRIs for Vestfold Hospital Trust from 2010 to 2020. The orange line shows the number of biopsies that did not result in PCa diagnosis, the grey shows biopsies made after the diagnosis of PCa, the yellow where biopsies resulted in PCa diagnosis, the blue line shows the number of new PCa in total and the green line shows the number of MRIs. Bx, biopsies; MRI, magnetic resonance imaging; PCa, prostate cancer.

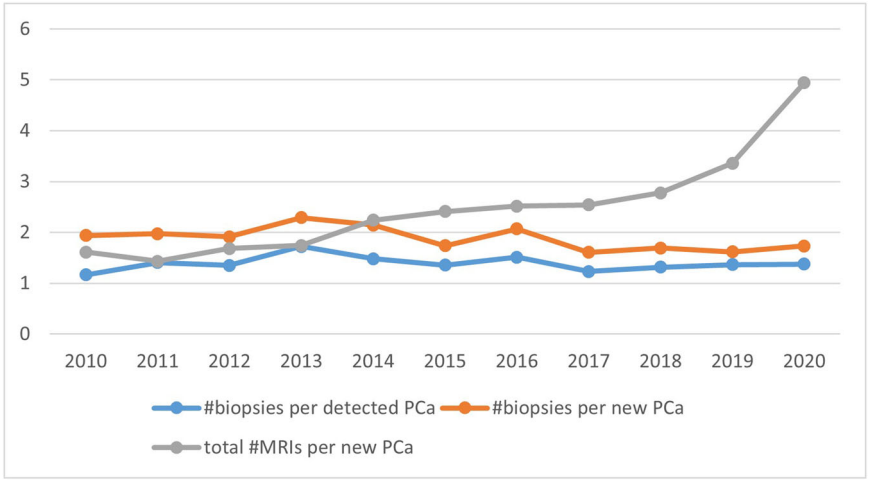

FIGURE 7 Number of biopsies per detected prostate cancers, number of biopsies per new prostate cancer and number of MRIs per new prostate cancer for each year at Vestfold Hospital Trust from 2010 to 2020. MRI, magnetic resonance imaging.

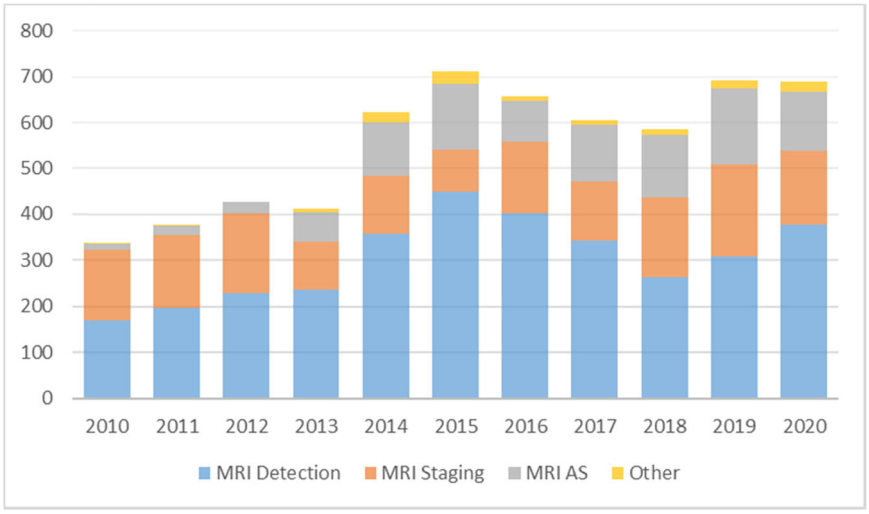

FIGURE 8 Number of MRIs used for detection, staging and AS at Vestfold Hospital Trust from 2010 to 2020. AS, active surveillance; MRI, magnetic resonance imaging

number of MRIs per PCa diagnosis consequently has more than tripled. Our results interestingly show that the number of MRIs has not been reduced during the pandemic year 2020 in Vestfold. Numbers for 2021 were not available at the time of submission.

The results raise the question of the value of the substantial increase in MRI utilisation. One potential consequence is an increase in the already substantial overdiagnosis of insignificant PCa.[6,18] While the results (as shown in Figure 2) have the typical signature of overdiagnosis, that is, a substantial increase in incidence without any mortality reduction[24] for the period 2002–2011, this is not so clear for the period 2013–2020. Noticeable, the small change in mortality during the same period is not very informative due to a substantial median expected survival for PCa of almost 15 years and the arrival of new medications increasing survival.

On the other hand, the substantial increase in MRI use without an increase in incidence may indicate overuse. That is, the increased number of MRI prostate do not contribute to the detection of new cases of cancer (Figures 1 and 2). Cancer in Norway shows an increasing percentage of locally advanced PCa at the expense of localized PCa over the last 20 years[4] (Figure 3). This obviously indicates a stage migration due to better staging with the increasing utilisation of MRI after the year 2000 and not a true increase. This is also demonstrated by the decreasing percentage of metastatic PCa driven by a rise in the incidence of 35% from 2005 to 2015. However, we found the main increase of MRIs is in detection and AS. This underlines that MRI has become an essential tool in the total management of PCa. MRI has made staging more accurate and biopsies more targeted with the result of changing the diagnostic spectrum.

The geographical variations in the number of MRIs indicate local practice variations and Figure 5 places Vestfold in a national context. Moreover, the increased commissioning of private imaging centres suggests that the MRI capacity at several radiological departments in public hospitals was depleted.

5.1 | Why do MRIs increase threefold from 2013 to 2021?

There might be several reasons for the substantial increase in prostate MRIs. One reason is the liberal use of PSA tests (despite

recommendations). Breidablik et al.[18] demonstrated substantial geographical variations in the use of PSA tests and a correlation between the number of PSA tests and the incidence of PCa in Norway in 2013. Hence, although there is no official screening programme for PCa in Norway, liberal PSA testing is a trigger for entering the public cancer care pathway for PCa and generates many extra MRIs.

The incidence of PCa increased until 2011, whereafter it was stable (Figure 2), indicating a minimal effect of MRI on PCa detection. However, the Vestfold data indicate that the number of MRIs for detection was increasing (Figure 8), and the number of MRIs per new PCa was increasing as well (Figure 7).

A second reason for the increase in MRIs could be the change in the diagnostic pathway resulting from the implemented fast-track system in Norway. According to its description, men with increased PSA or other symptoms consistent with PCa are referred to a urologist who assesses the inclusion in the fast-track system based on PSA, clinical examination, including rectal exploration, comorbidity assessment and patient's general condition.[25] To diagnose patients, the pathway includes b/mpMRI, a biopsy if indicated and supplemented by a staging protocol MRI in case of high-risk disease. The patients should be diagnosed or declared cancer-free within 34 days after the hospital receives the referral.[25] Interestingly, the implementation of the cancer pathways did not change the waiting times for treatment significantly.[26] Hence, the fast-track system may have facilitated a faster track to MRI but not to treatment.

Although there is a strong correlation between the number of MRIs and persons included in the fast-track pathway between 2015 and 2021, the increase in the number of MRIs started before implementing the fast-track system. Meaning that new MRI routines were commenced before the start of the new pathway. This indicates that professional change is a key driver of increased MRI use.

A third reason for the increased number of MRIs is imaging's role in reducing unnecessary biopsies. The number of negative biopsies in Vestfold declined from 2010 to 2020. Further, the incidence of metastatic cancers (M+) decreased while the number of cancers with positive regional lymph nodules (N+) increased, suggesting better and more sensitive diagnostics. However, although national data are not available, the results from this representative hospital trust clearly indicate that the number of biopsies per diagnosed cancer is reduced by 15%. In comparison, the number of MRIs per diagnosed cancer increased by 238% from 2013 to 2020. A question that cannot be directly answered from this study is how many MRIs it takes to reduce one unnecessary biopsy, as MRIs are used for many purposes.

A fourth explanation for the increase can be that MRIs are often used during AS and sometimes follow-ups post treatment. MRI in AS in Norway has been introduced gradually since 2012.[27] However, as shown in Figure 4, the increase in MRIs does not follow the increase in AS. One explanation can be that many patients are followed up with MRIs for many years.

A fifth explanation could be that MRI has improved the staging of PCa, which has increased the number of examinations. More accurate classification of cancers is experienced as a great benefit by professionals and may result in more targeted follow-up (reduced number of biopsies, less invasive procedures and more persons on AS). However, at the same time, MRIs can advance stage and grade migration (see below).

Finally, the increased number of MRIs could be due to increased focus on PCa in terms of fast-track implementation, political emphasis on cancer care and various patient organisation initiatives. Further, belief in advanced technology may be a factor for both patients and referrers, contributing to increased MRI utilisation.[28]

Hence, MRI increase are mainly in detection and AS, and there are many reasons for this increase. Accordingly, we need to pay attention to the implications of these findings.

5.2 | What are the implications of the increased number of MRIs?

A trifold use of MRIs comes at an extra cost of about two million USD per year, an reduced access to MRI services for other patient groups as the access to MRIs have not increased correspondingly. Hence, the costs must be balanced against the benefits.

As the number of biopsies is reduced even when the number of MRIs is unchanged, other factors seem to influence the number of biopsies more than the number of MRIs. Hence, more precise data are warranted to show if and how MRIs reduce the number of unnecessary biopsies.

Moreover, applying better initial tests[29] and fostering better adherence to guidelines[18] may reduce the number of unnecessary MRIs and biopsies. 97.9% of PCas are morphologically verified (either histologically or cytologically),[30] so the risk of misclassification is low. However, as long as PSA is used liberally and results in a great many false positives, the number of MRIs will be high.

One benefit of the extensive MRI use is the improved staging. At the same time, there is a shift in disease classification. The men diagnosed with PCa are getting younger and live longer, while the proportion with regional cancers is somewhat increasing. The median age at diagnosis during 2015–2019 was 69.0 years compared to 74.0 during 1985–1999 and 70.0 between 2000 and 2005. This is mainly attributed to earlier diagnosis.[31] Correspondingly, the 5-year relative survival rate has increased from 65.4% from 1990 to 1994 to 95.5% from 2015 to 2019, which has been attributed to improved diagnostics and treatment.[31] While more precise classification is good, disease spectrum shifts may foster an illusion of improved outcomes.

This means that the increased number of MRIs of the prostate may contribute to the reduction of biopsies. Still, MRIs are used for staging and AS so it is difficult to say how many MRIs are needed to avoid one unnecessary biopsy. However, it is legitimate to ask whether all MRIs are helpful,[32] which is why MRIs of the prostate have been targeted by the ChoosingWisely Initiative (https://www.choosingwisely.org/patient-resources/imaging-tests-for-early-prostate-cancer/). Our results also

align with an assessment of the Norwegian fast-track system, which concludes that many unnecessary MRIs do not improve patient trajectory or outcomes.[13]

It is important to acknowledge that prostate MRIs appear useful for clinicians in all three aspects (detection, staging, AS) although the predictive value is low.[33] The important challenge is to demonstrate the outcomes for these uses.

5.3 | What can and should we do?

While the increased number of MRIs can be related to the reduced number of negative biopsies, more advanced staging and extended AS, the exact benefit of extended MRI use is difficult to document. This is crucial as the many extra MRIs burden imaging departments, as they generate significant opportunity costs in terms of delayed access, diagnosis, an for other groups of patients.

Applying better entrance tests or improved urological assessment[13] may be one way to limit the harm. Several biomarkers have been introduced (EAU guidelines) and are recommended as a pre-MRI and prebiopsy test to reduce the diagnostic burden,[29] but actually have its highest accuracy in combination with MRI. A European initiative has also proposed an algorithm based on PSA and risk calculators.[34] Whether this will reduce the number of unnecessary MRIs is yet to be seen.

5.4 | Limitations

We have limited national MRI data to 2013–2021 as the data are of poorer quality from 2000 to 2012 as there was a shift in examination codes and registration procedures. Nonetheless, there was a steady increase in the number of MRI examinations of the prostate from 2000 to 2012 and the presented data concur with other studies.[35]

As indicated, a data registry-based study cannot assess the value of individual MRI examinations, and we can only infer about the mechanisms behind our findings. Furthermore, this study does not include in-patient examinations, hence providing only a partial picture of the use of MRI for PCa. However, the use of in-patient prostate examinations in Norway is low.

For biopsy data, we only have access to data from one hospital trust (Vestfold), representing 5% of the Norwegian population. Although this appears representative (age, gender, rural/urban), we cannot infer from these to the national biopsy numbers. Moreover, there may be flaws in the data. For example, 2020 appears to have a very low number of detected PCa, which may be an outlier. Nonetheless, the numbers are valuable for reflection on the mechanisms. Moreover, we provide numbers for both MRIs and biopsies in one region, facilitating more detailed reflections.

The study has only used descriptive statistics and basic correlations (Pearson). More advanced statistics may reveal connections between various factors but also be subject to criticism of data dredging. Therefore, this study has been conservative. Costs were calculated as reimbursement costs + copay + lump sum, which in 2020 was 203 USD. This is somewhat lower than in other countries. A recent study reported MRI costs in the Netherlands to be EUR 345, in the United States to be USD 524 and in Canada to be 900 USD.[36] Hence, the real costs can be significantly higher than the ones calculated here. However, as no better cost estimates are available, we report the official numbers.

We acknowledge potential underlying selection bias and confounding. One possible confounding factor is temporal changes in MRI technique, which has been discussed above. Another is health insurance billings over time, which is not likely to have influenced the practice in Norway. There may also be different disease characteristics between the MRI and non-MRI users, and there may be a difference between MRI used as a staging procedure or as a diagnostic tool. However, in a small country like Norway, the same persons are doing various procedures.

As this is a descriptive study, we have not said anything about what would be appropriate use of MRI for the prostate.[37–39] Nonetheless, the study provides input for discussions on (in)appropriateness.

6 | CONCLUSION

This study shows that the number of MRIs of the prostate has tripled from 2013 to 2020 (Q1) with a substantial opportunity cost and that the increased utilisation started before the introduction of a fast-track system for PCa care in Norway. The incidence of PCa has been stable at about 5000 cases per year which corresponds to 178 per 100,000 men (Q2), hence there is no typical signature of overdiagnosis from the increased MRIs. The clinical staging has changed substantially during this period (Q3), resulting in potential stage and grade migration. The number of negative biopsies is somewhat reduced (Q4). The number of persons on AS has increased during this period (Q4). However, these changes are only partly due to the increase in the number of MRIs, as they occur even when the number of MRIs is stable. While we have identified many reasons for the rise in prostate MRIs, little evidence exists of their outcomes for patients.

Therefore, we need more evidence of how the increase in MRI examinations improve the detection and staging of PCa and how the increased number of MRIs due to AS contributes to improving people's health, i.e., that it is worth the extra costs.

AUTHOR CONTRIBUTIONS

Bjørn Hofmann made the outline of this study and the first draft of the manuscript. Elin Kjelle provided the first analysis of the MRIs data supplemented by analyses by Bjørn Hofmann. Erik Skaaheim Haug provided the analyses of the biopsy data, the local MRI data, and the staging data. Bjørn Hofmann provided the economic analysis. All authors contributed to several revisions of the

manuscript. All authors have approved of the final version of the manuscript.

ACKNOWLEDGEMENT

We are most thankful to the Norwegian Health Economics Administration (HELFO) and to the Norwegian Cancer Registry for providing data for the study. The research is funded by the Norwegian Research Council (IROS 302503).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

ETHICS APPROVAL

Not applicable.

REFERENCES

1. Culp MB, Soerjomataram I, Efstathiou JA, Bray F, Jemal A. Recent global patterns in prostate cancer incidence and mortality rates. *Eur Urol*. 2020;77(1):38-52.
2. Löffeler S, Halland A, Weedon-Fekjær H, Nikitenko A, Ellingsen CL, Haug ES. High Norwegian prostate cancer mortality: evidence of over-reporting. *Scand J Urol*. 2018;52(2):122-128.
3. Drost FJH, Osses DF, Nieboer D, et al. Prostate MRI, with or without MRI-targeted biopsy, and systematic biopsy for detecting prostate cancer. *Cochrane Database Syst Rev*. 2019;4(4):CD012663.
4. The Cancer Registry of Norway. *The Cancer Registry of Norway Online Statistics. Secondary The Cancer Registry of Norway Online Statistics*. The Cancer Registry of Norway; 2021. https://sb.kreftregisteret.no/insidens/
5. Norwegian Institute of Public Health. *Cause-of-death registry at the Norwegian Institute of Public Health. Secondary Cause-of-death registry at the Norwegian Institute of Public Health*. Norwegian Institute of Public Health; 2021.
6. Walter S, Hu J, Talala K, Tammela T, Taari K, Auvinen A. Estimating the rate of overdiagnosis with prostate cancer screening: Evidence from the finnish component of the european randomized study of screening for prostate cancer. *Cancer Causes Control*. 2021;32:1299-1313.
7. Baco E, Rud E, Vlatkovic L, et al. Predictive value of magnetic resonance imaging determined tumor contact length for extracapsular extension of prostate cancer. *J Urol*. 2015;193(2):466-472.
8. Rud E, Klotz D, Rennesund K, et al. Detection of the index tumour and tumour volume in prostate cancer using T2-weighted and diffusion-weighted magnetic resonance imaging (MRI) alone: T2W and DW MRI for detecting prostate cancer. *BJU Int*. 2014;114(6b):E32-E42.
9. McAllister BJ, Jarvis AK, Smith SM, Walton TJ. Benefits of pre-biopsy multi-parametric magnetic resonance imaging scanning in the initial assessment of prostate cancer. *Int J Urol Nurs*. 2021;15(1):33-38.
10. Wallström J, Geterud K, Kohestani K, et al. Bi-or multiparametric MRI in a sequential screening program for prostate cancer with PSA followed by MRI? Results from the Göteborg prostate cancer screening 2 trial. *Eur Radiol*. 2021;31:8692-8702.
11. Timsit M-O, Baciarello G, Hennequin C, et al. *Effectiveness of Early Diagnosis for Prostate Cancer Based on PSA and Multiparametric MRI: A Simulation Study*. American Society of Clinical Oncology; 2021.
12. NICE Guideline Updates Team. *Prostate Cancer: Diagnosis and Management*. NICE; 2019.
13. Billdal DC. *Bedre seleksjon av pasienter henvist til MR av prostata ved forhøyet PSA ellermistanke om prostatakreft*. NTNU; 2021.
14. Roobol MJ. Active surveillance for prostate cancer—will the discoveries of the last 5 years change the future? *Transl Androl Urol*. 2021;10(6):2828-2831.
15. Lima CA, da Silva BEB, Hora EC, et al. Trends in prostate cancer incidence and mortality to monitor control policies in a northeastern Brazilian state. *PLoS One*. 2021;16(3):e0249009.
16. Pathirana T, Hayen A, Doust J, Glasziou P, Bell K. Lifetime risk of prostate cancer overdiagnosis in Australia: quantifying the risk of overdiagnosis associated with prostate cancer screening in Australia using a novel lifetime risk approach. *BMJ Open*. 2019;9(3):e022457.
17. Loeb S, Bjurlin MA, Nicholson J, et al. Overdiagnosis and overtreatment of prostate cancer. *Eur Urol*. 2014;65(6):1046-1055.
18. Breidablik HJ, Meland E, Aakre KM, Førde OH. PSA measurement and prostate cancer–overdiagnosis and overtreatment? *Tidsskrift for den Norske Legeforening*. 2013;133(16):1711-1716.
19. Boehm K, Borgmann H, Ebert T, et al. Stage and grade migration in prostate cancer treated with radical prostatectomy in a large German multicenter cohort. *Clin Genitourin Cancer*. 2021;19(2):162-166.e1.
20. McCaffery K, Nickel B, Pickles K, et al. Resisting recommended treatment for prostate cancer: a qualitative analysis of the lived experience of possible overdiagnosis. *BMJ Open*. 2019;9(5):e026960.
21. Larsen IK, Småstuen M, Johannesen TB, et al. Data quality at the Cancer Registry of Norway: an overview of comparability, completeness, validity and timeliness. *Eur J Cancer*. 2009;45(7):1218-1231.
22. Office Excel. 2013.
23. Stavrinides V, Giganti F, Trock B, et al. Five-year outcomes of magnetic resonance imaging–based active surveillance for prostate cancer: a large cohort study. *Eur Urol*. 2020;78(3):443-451.
24. Welch HG, Kramer BS, Black WC. Epidemiologic signatures in cancer. *N Engl J Med*. 2019;381(14):1378-1386.
25. Guldvåg B. Pakkeforløp prostatakreft. *Helsedirektoratet*. Norwegian Directorate of Health; 2014.
26. Nilssen Y, Brustugun OT, Tandberg Eriksen M, et al. Decreasing waiting time for treatment before and during implementation of cancer patient pathways in Norway. *Cancer Epidemiology*. 2019;61:59-69.
27. Norwegian Cancer Registry. *Year Report 2014. Nasjonalt kvalitetsregister for prostatakreft*. Norwegian Cancer Registry; 2014.
28. Hofmann B. Biases and imperatives in handling medical technology. *Health Policy and Technology*. 2019;8(4):377-385.
29. Viste E, Vinje CA, Lid TG, et al. Effects of replacing PSA with Stockholm3 for diagnosis of clinically significant prostate cancer in a healthcare system–the Stavanger experience. *Scand J Prim Health Care*. 2020;38(3):315-322.
30. Nilssen Y, Brustugun OT, Eriksen MT, Haug ES, Naume B, Møller B. Patient and tumour characteristics associated with inclusion in cancer patient pathways in Norway in 2015–2016. *BMC Cancer*. 2020;20(1):488. doi:10.1186/s12885-020-06979-y
31. The Cancer Registry of Norway. *Cancer in Men in Norway 2020*. The Cancer Registry of Norway; 2021.
32. Levin DC, Rao VM. Reducing inappropriate use of diagnostic imaging through the choosing wisely initiative. *J Am Coll Radiol*. 2017;14(9):1245-1252. doi:10.1016/j.jacr.2017.03.012
33. Westphalen AC, McCulloch CE, Anaokar JM, et al. Variability of the positive predictive value of PI-RADS for prostate MRI across 26 centers: experience of the society of abdominal radiology prostate cancer disease-focused panel. *Radiology*. 2020;296(1):76-84. doi:10.1148/radiol.2020190646
34. Van Poppel H, Roobol MJ, Chapple CR, et al. Prostate-specific antigen testing as part of a risk-adapted early detection strategy for

prostate cancer: European Association of Urology Position and Recommendations for 2021. *Eur Urol*. 2021;80:703-711.
35. Aas K. *Prostate Cancer Without Distant Metastases: Treatment and Mortality in Norway 2001-2016*; Thesis, University of Oslo, 2021.
36. Hutchinson R, Lotan Y. Cost consideration in utilization of multi-parametric magnetic resonance imaging in prostate cancer. *Transl Androl Urol*. 2017;6(3):345-354. doi:10.21037/tau.2017.01.13
37. Makarov DV, Desai R, Yu JB, et al. Appropriate and inappropriate imaging rates for prostate cancer go hand in hand by region, as if set by thermostat. *Health Aff*. 2012;31(4):730-740. doi:10.1377/hlthaff.2011.0336
38. Oakes AH, Sharma R, Jackson M, Segal JB. Determinants of the overuse of imaging in low-risk prostate cancer: a systematic review. *Urol Oncol*. 2017;35(11):647-658. doi:10.1016/j.urolonc.2017.08.025
39. Patel S, Rongen JJ, Fütterer JJ, Boltyenkov A, Rovers MM. The role of multiparametric magnetic resonance imaging in active surveillance for men with low-risk prostate cancer: a cost-effectiveness modeling study. *Eur Urol Oncol*. 2018;1(6):476-483. doi:10.1016/j.euo.2018.05.007

How to cite this article: Hofmann B, Haug ES, Andersen ER, Kjelle E. Increased magnetic resonance imaging in prostate cancer management—What are the outcomes? *J Eval Clin Pract*. 2022;1-10. doi:10.1111/jep.13791