

Completeness of *RET* testing in patients with medullary thyroid carcinoma in Denmark 1997–2013: a nationwide study

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Background: The completeness of *RE*arranged during Transfection (*RET*) testing in patients with medullary thyroid carcinoma (MTC) was recently reported as 60%. However, the completeness on a population level is unknown. Similarly, it is unknown if the first Danish guidelines from 2002, recommending *RET* testing in all MTC patients, improved completeness in Denmark. We conducted a nationwide retrospective cohort study aiming to evaluate the completeness of *RET* testing in the Danish MTC cohort. Additionally, we aimed to assess the completeness before and after publication of the first Danish guidelines and characterize MTC patients who had not been tested.

Methods: The study included 200 patients identified from the nationwide Danish MTC cohort 1997–2013. To identify *RET* tested MTC patients before December 31, 2014, the MTC cohort was cross-checked with the nationwide Danish *RET* cohort 1994–2014. To characterize MTC patients who had not been *RET* tested, we reviewed their medical records and compared them with MTC patients who had been tested.

Results: Completeness of *RET* testing in the overall MTC cohort was 87% (95% CI: 0.81–0.91; 173/200). In the adjusted MTC cohort, after excluding patients diagnosed with hereditary MTC by screening, completeness was 83% (95% CI: 0.76–0.88; 131/158). Completeness was 88% (95% CI: 0.75–0.95; 42/48) and 81% (95% CI: 0.72–0.88) (89/110) before and after publication of the first Danish guidelines, respectively. Patients not *RET* tested had a higher median age at diagnosis compared to those *RET* tested. Median time to death was shorter in those not tested relative to those tested.

Conclusion: The completeness of *RET* testing in MTC patients in Denmark seems to be higher than reported in other cohorts. No improvement in completeness was detected after publication of the first Danish guidelines. In addition, data indicate that advanced age and low life expectancy at MTC diagnosis may serve as prognostic indicators to identify patients having a higher likelihood of missing the compulsory *RET* test.

Keywords: *RET* testing, medullary thyroid carcinoma, Denmark

Introduction

Medullary thyroid carcinoma (MTC) is a rare neuroendocrine tumor with an incidence of 0.19 per 100,000 per year and a prevalence of 3.8 per 100,000 inhabitants.¹ MTC is divided into sporadic (75%) and hereditary (25%).^{1,2} The latter form occurs as part of multiple endocrine neoplasia (MEN)2, which is an autosomal-dominant inherited cancer syndrome, where virtually all patients develop MTC and variable proportions develop pheochromocytoma, primary hyperparathyroidism, cutaneous lichen amyloidosis, Hirschsprung's disease, ganglioneuromatosis of the aerodigestive tract, and facial, ophthalmologic, and skeletal abnormalities.³ Conversely, the sporadic form is not known to have familial implications or predispositions to other endocrine neoplasia.

sia. It is thus important to distinguish hereditary MTC from sporadic MTC.

As germline mutations of the *RE*arranged during Transfection (*RET*) proto-oncogene are present in practically all patients with hereditary MTC and absent in patients with sporadic MTC, distinction is best made by *RET* testing on peripheral blood.⁴ Presence of a *RET* germline mutation has serious implications for index cases and their families. Hence, index cases will need lifelong follow-up and screening for MEN2 manifestations other than MTC. Meanwhile, all first-degree relatives should be offered genetic counseling and genetic testing. If the relatives are positive of the family germline mutation, virtually all will require prophylactic thyroidectomy with the timing depending on the specific mutation. As for the index cases, relatives will also warrant lifelong follow-up for development of MEN2 manifestations. Thus, for several years, international guidelines have recommended *RET* testing of all patients with MTC.^{3,5,6}

The first study aiming to determine the completeness of *RET* testing in MTC patients recently reported a completeness of 60% (86/142) in a single center.⁷ This completeness is remarkably discordant with both past and current recommendations.^{3,5,6} However, it is unknown if such low completeness is also the standard when examining a population-based cohort.

In Denmark, *RET* testing has been available since September 1994.⁸ Seven years later, in February 2002, the first Danish guidelines, recommending *RET* testing of all patients with MTC, were published.⁹ In the meantime, it is unknown if these guidelines have improved completeness of *RET* testing in MTC patients.

Consequently, we conducted the first population-based study aiming to evaluate the overall completeness of *RET* testing in a nationwide MTC cohort. Additionally, we aimed to assess the completeness before and after publication of the Danish guidelines and characterize MTC patients who had not been tested.

Methods

Design and setting

This investigation is a nationwide retrospective cohort study including all patients with newly diagnosed MTC in Denmark between January 1, 1997, and December 31, 2013.

Data sources

The Danish MTC cohort

This cohort formed the basis for the study. It initially comprised 476 patients diagnosed with histological (n=474) or cytological (n=2) MTC in Denmark between January 1960

and December 2014 and was constructed through three nationwide registries: the Danish Cancer Registry, the Danish Thyroid Cancer Database, and the Danish Pathology Register as described in detail elsewhere.^{1,10–13,36} The Danish Cancer Registry, the Danish Thyroid Cancer Database, and the Danish Pathology Register are considered to cover the whole country from 1987, 1996, and 1997, respectively. The MTC cohort consisted of an uncertain period from 1960 to 1996, where complete coverage could not be guaranteed, and a nationwide period from 1997 to 2014, where coverage of the entire country was considered complete. TNM staging in the MTC cohort was performed according to the seventh and eighth editions of the American Joint Committee on Cancer Staging Manual.^{14,15}

The Danish *RET* cohort

This nationwide cohort was cross-checked with the Danish MTC cohort to determine the completeness of *RET* testing. The cohort initially contained all 1,583 patients *RET* tested in Denmark between September 1994 and December 2014. However, in the process of this study, we discovered three *RET* tested patients, whose test had initially been missed. Accordingly, the Danish *RET* cohort comprises 1,586 *RET* tested patients from 1994 to 2014. There was virtually no lag time between when a test was performed and when it was registered in the Danish *RET* cohort, as tests were registered instantly upon requisition. The cohort has been described and used on several occasions.^{8,16}

Study participants

From the Danish MTC cohort, we extracted all 224 patients diagnosed in the nationwide period from January 1, 1997, to December 31, 2014. As *RET* testing post mortem is not considered a standard procedure in Denmark, we excluded all patients (n=4) diagnosed at autopsy.¹⁷ The original end date of the MTC cohort is similar to that of the *RET* cohort (December 31, 2014). Thus, to provide at least 1 year to detect *RET* testing in patients diagnosed during the last year (2013) of the MTC cohort, we excluded the patients (n=20) diagnosed from January 1, 2014, to December 31, 2014. This formed an overall MTC cohort comprising 200 patients, who were alive at the time of diagnosis in the study period from January 1, 1997, to December 31, 2013.

Virtually, all patients diagnosed with hereditary MTC by screening (asymptomatic) will have undergone predictive *RET* testing. Including such patients in the calculations may cause a false increase in completeness of *RET* tested

MTC patients for the whole study period and for periods where large families with hereditary MTC were discovered. The latter could potentially bias a comparison of completeness between two periods. We therefore excluded patients diagnosed with hereditary MTC by screening ($n=42$). This yielded an adjusted MTC cohort of 158 patients diagnosed from January 1, 1997, to December 31, 2013.

Based on the publication date of the first Danish guidelines, February 7, 2002, we divided the adjusted MTC cohort into an early period comprising 48 patients diagnosed from 1, 1997, to February 6, 2002, and a late period comprising 113 patients diagnosed from February 7, 2002, to December 31, 2013.

For each patient, data were collected from the MTC and *RET* cohort on sex, date, and TNM stage at MTC diagnosis, *RET* test result and date of result, and survival time. The latter was calculated as the time from MTC diagnosis until death, emigration, or last follow-up (January 1, 2014), whichever came first. To explain why some patients had not been *RET* tested, we reviewed the medical records of these patients for any remarks of *RET* or genetic testing.

Statistical analyses

Completeness was calculated as the number of *RET* tested MTC patients divided by the total number of MTC patients and was given in percentage with 95% CI. Continuous data were presented as median and IQR. Categorical data were presented as absolute and relative frequencies. Continuous and categorical data were tested on univariate analysis with the Mann–Whitney–Wilcoxon-rank test and Fischer's exact test as appropriate. In survival data, censoring was taken into account by the Kaplan–Meier method. All tests were two-sided, and P -values <0.05 were considered as significant. All analyses were done using Stata® 15.1 (StataCorp LP, College Station, TX, USA).

The investigation was approved by the Danish Health Authority (3-3013-395/3) and the Danish Data Protection Agency (18/17801).

Results

Overall completeness

In the overall MTC cohort, 87% (95% CI: 0.81–0.91; 173/200) of the patients diagnosed from January 1, 1997, to December 31, 2013, had been *RET* tested. Of the *RET* tested patients, 71% (122/173) had sporadic MTC and 29% (51/173) had hereditary MTC. In the latter patients, the following *RET* mutations were detected: C611W ($n=3$), C611Y ($n=31$), C618F ($n=1$), C618Y ($n=3$), C620R ($n=4$), C634Y+Y791F

($n=1$), L790F ($n=1$), A883F ($n=1$) and M918T ($n=6$). Several of these patients have been reported earlier.^{17–23}

In the adjusted MTC cohort, in which patients diagnosed with hereditary MTC by screening had been excluded, the completeness of *RET* testing was 83% (95% CI: 0.76–0.88; 131/158).

Completeness before and after guidelines

In the early period, 88% (95% CI: 0.75–0.95; 42/48) had been *RET* tested, while this was the case for 81% (95% CI: 0.72–0.88; 89/110) in the late period. Completeness of *RET* testing in the adjusted MTC cohort according to year of MTC diagnosis is depicted in Figure 1.

Not *RET* tested

In the adjusted MTC cohort, 17% (27/158) of patients had not been *RET* tested (Table 1). For 20 patients, we found no reason for the lack of *RET* testing, as no medical record was available for two patients and no remark of testing was noted in the medical record of 18 patients. In three patients, testing was not performed due to advanced age. *RET* testing was planned in two patients but never performed for reasons unknown. Two patients had been tested for MEN1 instead of MEN2.

Table 2 lists characteristics for those *RET* tested and those not *RET* tested. At the time of MTC diagnosis, those not *RET* tested had a higher median age and higher proportion of distant metastases compared to those *RET* tested. At the last follow-up, the median time to death was shorter in those not *RET* tested compared to those *RET* tested.

Discussion

Although MEN2 is rare, recognition of the syndrome by *RET* testing is crucial, as early thyroidectomy before MTC has spread beyond the thyroid often confers the best chance for cure.^{13,24,37}

In this nationwide study, we report a completeness of *RET* testing in $>80\%$ of patients diagnosed with MTC in Denmark from 1997 to 2013. We found no change in completeness when comparing completeness in periods before and after publication of the first Danish guidelines on the subject. Additionally, it seems that MTC patients with an advanced age and a short life expectancy have a higher likelihood of not being *RET* tested.

Limitations

The completeness estimate in this study is limited by the possibility that some patients from the MTC cohort (1997–2013) may have been tested after the end date of the *RET* cohort

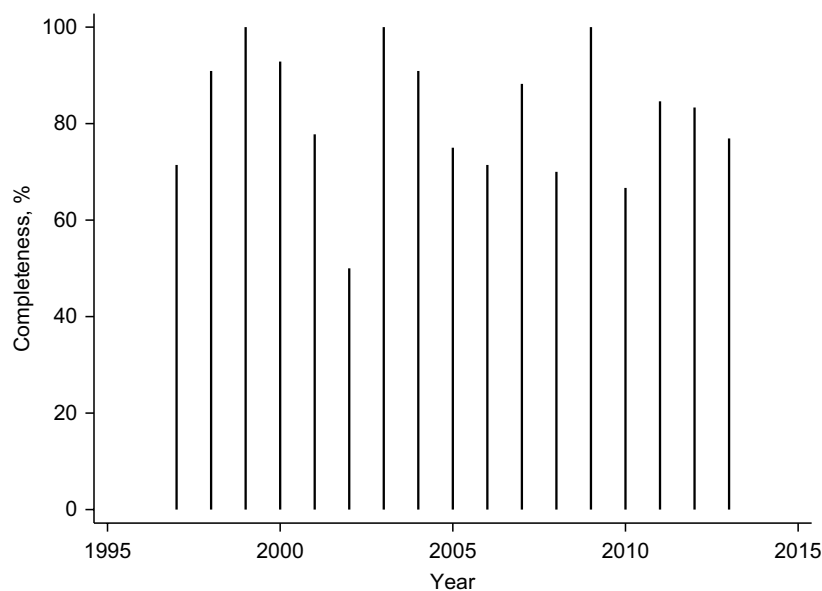


Figure 1 Completeness of *RET* testing in patients with MTC in Denmark from 1997 to 2013.

Abbreviations: *RET*, *RE*arranged during *Transfection*; MTC, medullary thyroid carcinoma.

Table 1 Characteristics of 27 patients diagnosed with MTC in Denmark 1997–2013 but not *RET* tested before the end date of the Danish *RET* cohort, December 31, 2014

Patient No.	Sex	At diagnosis		At last follow-up		Medical record review
		Age, years	TNM ^a	Status	Survival ^b	
1	F	76	T1bN0M0	Dead	1.2	No remark of <i>RET</i> testing
2	F	48	T1bN0M0	Alive	14.9	No remark of <i>RET</i> testing
3	F	77	T4aN0M0	Alive	13.9	No remark of <i>RET</i> testing
4	M	82	T3N1bM0	Dead	1.2	No remark of <i>RET</i> testing
5	M	80	T4aN1bM1	Dead	0.3	No remark of <i>RET</i> testing
6	M	44	T3N0M0	Dead	0.6	No remark of <i>RET</i> testing
7	F	75	T2N1bM1	Dead	1.3	No remark of <i>RET</i> testing
8	F	75	TXN0M1	Dead	2.6	No remark of <i>RET</i> testing
9	M	60	T4aN1aM1	Dead	0.5	No remark of <i>RET</i> testing
10	F	45	T2N1aM0	Alive	6.8	No remark of <i>RET</i> testing
11	F	75	T4aN1bM1	Dead	0.1	No remark of <i>RET</i> testing
12	F	71	T3N1bM1	Dead	0.2	No remark of <i>RET</i> testing
13	M	40	T4aN1bM1	Dead	1.0	No remark of <i>RET</i> testing
14	M	62	T1bN1bM0	Alive	2.6	No remark of <i>RET</i> testing
15	M	66	T2N0M0	Alive	2.2	No remark of <i>RET</i> testing
16	M	75	T2N1bM0	Alive	1.8	No remark of <i>RET</i> testing
17	F	82	T1aN0M0	Dead	2.9	No remark of <i>RET</i> testing
18	F	71	T2N1bM0	Dead	0.7	No remark of <i>RET</i> testing
19	F	74	T1aN1bM0	Dead	1.9	No medical record available
20	F	73	T4aN1bM0	Dead	0.05	No medical record available
21	F	70	T1bN0M0	Alive	12.5	<i>RET</i> testing not performed due to advanced age
22	M	84	T4aN1aM0	Dead	1.1	<i>RET</i> testing not performed due to advanced age
23	F	76	T2N1bM0	Dead	6.4	<i>RET</i> testing not performed due to advanced age and childlessness
24	F	54	T2N0M0	Alive	12.7	<i>RET</i> testing planned but never performed
25	M	69	T4aN1bM0	Dead	2.2	<i>RET</i> testing planned but never performed
26	F	62	T3N0M0	Alive	6.1	<i>RET</i> testing ordered but <i>MEN1</i> testing performed
27	F	45	T1aN0M0	Alive	6.2	<i>RET</i> testing possibly performed but could not be documented

Notes: ^aStaging was based on the American Joint Committee on Cancer's seventh and eighth editions.^{14,15} ^bSurvival was defined as the time from diagnosis of MTC until death, emigration, or last follow-up (December 31, 2014), whichever came first.

Abbreviations: F, female; *RET*, *RE*arranged during *Transfection*; M, male.

Table 2 Characteristics of 158 patients evaluated for *RET* testing following diagnosis of MTC in Denmark from 1997 to 2013

Characteristics	<i>RET</i> tested (n=131)	Not <i>RET</i> tested (n=27)
At diagnosis		
Sex, n (%)		
F	84 (64)	17 (63)
M	47 (36)	10 (37)
Age, median (IQR), years	55.5 (43.0–65.5)	71.5 (60.0–76.0)
T category, n (%)		
T0	1 (1)	0
T1	39 (30)	7 (26)
T2	44 (34)	7 (26)
T3	18 (14)	4 (15)
T4	28 (21)	8 (30)
Tx	1 (1)	1 (4)
N category, n (%)		
N0	57 (44)	11 (41)
N1	74 (56)	16 (59)
M category, n (%)		
M0	119 (91)	20 (74)
M1	12 (9)	7 (26)
TNM stage ^a , n (%)		
I	21 (16)	5 (19)
II	31 (24)	4 (15)
III	10 (8)	1 (4)
IV	68 (52)	17 (63)
Unknown	1 (1)	0
At follow-up		
Survival status		
Alive	89 (68)	10 (37)
Dead	42 (32)	17 (63)
Time to death, median ^b (95% CI) (years)	14.7 (11.3–NA)	2.2 (1.0–NA)

Notes: Owing to rounding up, not all sums of percentages fit. ^aStaging was based on the American Joint Committee on Cancer's seventh and eighth editions.^{14,15} ^bTaking censoring into account by the Kaplan–Meier method. No upper limit for the 95% CI due to too few events.

Abbreviations: F, female; M, male; M, metastasis; MTC, medullary thyroid carcinoma; N, node; NA, not available; *RET*, R*E*arranged during *T*ransfection; T, tumor.

(1994–2014). This could result in a marginally higher completeness than reported. In our experience, however, most patients are tested within the first year of MTC diagnosis.

Our description of reasons for the lack of *RET* testing in MTC patients was limited by the retrospective collection of data from medical records. Medical records were available for 93% (25/27) of patients who had not been tested. However, 18 medical records contained no remark of *RET* testing, preventing us from drawing further conclusions in these patients. A reasonable thought, however, may be that *RET* testing in these cases was simply forgotten or not considered.

Overall completeness

In the present study, we found a *RET* testing completeness of more than 80%. Recently, the first study aiming to deter-

mine the completeness of *RET* testing in MTC patients was published. The study was based on the Southern California Kaiser Permanente health care network and reported a completeness of 60% (86/142).⁷ Often such differences between Danish and US cohorts may be explained by a different access to health care systems. However, all patients from the Californian study obtained medical insurance from the Kaiser Permanente health care network and all patients in Denmark are provided with free public health care. Thus, there seems to be equal access to health care in the two study cohorts. Another potential explanation could be differences in the setup of *RET* testing in the two cohorts. After the diagnosis of MTC in Denmark, patients are offered *RET* testing at the surgical department or referred directly to another department that offers testing. The absent details of testing setup in the Kaiser Permanente study, however, prevent direct comparison. On the other hand, the Kaiser study described an outreach project, in which 32 MTC patients, who had not been *RET* tested, were scheduled for genetic counseling. However, only 25% (8/32) showed interest for their appointment and accepted *RET* testing. Although having no direct Danish comparison, one could speculate that the reluctance toward *RET* testing may have been higher in the Kaiser Permanente study cohort compared to the Danish cohort.

Recent institutional studies, with inclusion periods roughly similar to ours, have reported a *RET* testing completeness of 39%–66% in MTC patients undergoing thyroid surgery.^{25–27} In addition, in this context, the completeness in Denmark seems fairly high. However, relative to the recommendation of a completeness of 100%, the Danish completeness is not sufficient.

Completeness before and after guidelines

We saw no change in completeness of *RET* tested patients with MTC diagnosed before and after publication of the first Danish guidelines. Thus, judged solely from this, the Danish guidelines did not improve outcome, as is often a goal for clinical guidelines.²⁸ On the other hand, as we also did not find a decrease in the completeness, the guidelines may have helped to maintain a roughly unchanged completeness in the late period compared to that in the early period. One may also argue that the completeness in the early period was unexpectedly high (88%), potentially due to a commendable awareness prompted by the discovery in 1993 and 1994 that mutations in the *RET* proto-oncogene cause hereditary MTC.^{29–33} To the best of our knowledge, no other study has investigated the temporal changes in *RET* testing completeness of MTC patients with respect to national guidelines.

However, research groups from the US have conducted population-based studies exploring surgical practice in regard to MTC guidelines.^{34,35} Thus, a study of 2,033 MTC patients included from the Surveillance, Epidemiology, and End Results Program database 1973–2006 examined adherence to the 2009 American Thyroid Association guidelines and found that 41% of patients diagnosed with MTC from 1988 to 2006 received surgical treatment that was out of line with the guidelines.^{6,34} Additionally, a study of 609 MTC patients identified from the California Cancer Registry 1999–2012 reported that central neck dissection was underused despite recommendation of this procedure in both the 2009 and 2015 American Thyroid Association guidelines.³⁵ Thus, there are indications that other parts of the clinical practice for MTC are also discordant with guidelines.

Not *RET* tested

To identify MTC patients having a higher likelihood of missing the recommended *RET* test, we performed a medical record review in patients who had not been *RET* tested. Although the circumstances of not *RET* testing were described in a limited number of medical records, there seems to be a fraction of patients (3/27) who were not *RET* tested due to advanced age. This is consistent with the higher age at diagnosis noted in those not tested relative to those tested. Although remaining speculative, this may also apply for some of the patients who were not tested and had a medical record with no remark of *RET* testing. Additionally, 39% (7/18) of patients with no remark of *RET* testing in the medical record lived less than 1 year from MTC diagnosis to death. Thus, some patients may simply not live long enough to undergo *RET* testing (as they often need to be referred to and convened by the *RET* testing department). This is supported by the lower median time from diagnosis to death found when comparing those not tested to those tested. In addition, we found a higher proportion of distant metastases among those not tested compared to those tested. The difference, however, disappeared after Bonferroni correction in a logistic regression model that also incorporated sex, age, T category, and N category as predictor variables. Altogether, this could indicate that a low life expectancy and an advanced age at MTC diagnosis may serve as prognostic indicators for identification of MTC patients having a higher likelihood of missing the compulsory *RET* test. The differences among the tested and untested patients with regard to median age at diagnosis and median time to death are substantial in a clinical context, where they may be used as markers to find patients needing special attention to secure that *RET* testing

is performed. This may improve the completeness of *RET* testing. Another way to improve completeness could be to perform *RET* testing immediately when the patient attending the surgical outpatient clinic is informed about the diagnosis of MTC. Among the Danish thyroid cancer centers, this setup is used in one center, while the remaining three centers use a two-tier setup, in which patients after diagnosis are referred to another department, where testing is then performed.

Conclusion

The completeness of *RET* testing in MTC patients in Denmark seems to be higher than reported in other cohorts. No improvement in completeness was detected after publication of the first Danish guidelines recommending *RET* testing in all MTC patients. In addition, our data indicate that advanced age and low life expectancy at MTC diagnosis may serve as prognostic indicators to identify patients having a higher likelihood of missing the compulsory *RET* test.

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Disclosure

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