Clinical Overview of Thyroid Cancer and Recent Advances in Treatment

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Abstract

Thyroid cancer represents a spectrum of biological and molecular activity. As such it can behave in a variety of ways. This makes metastatic thyroid cancer challenging to manage. In advanced rapidly progressive thyroid cancer new agents and multimodality care represent promising therapeutic options for patients. However, these agents are not without risk and clinicians must be judicious with their use, weighing toxicities, quality of life and likely benefits. We review the presentation, treatment and prognosis of thyroid cancer subtypes as well as the recent developments in targeted therapy for medullary thyroid cancer. We discuss the role of cytotoxic therapy in thyroid cancer and review recent trials of novel agents and currently recruiting trials.

Keywords: Thyroid cancer; prognosis; Cytotoxic therapy; Recruiting trials

Introduction and Overview of Thyroid Cancer

Thyroid cancer is rare, comprising less than 1% of all cancers diagnosed. The incidence is rising with a 2.4 fold increase over the last thirty years however mortality rates are stable [1]. Annually in Ireland 162 cases of thyroid cancer are recorded [2]. 68% present with localized disease 4% present with metastatic disease at diagnosis [3]. As Recurrence rates can be as high at 30%. Thyroid cancer arises from two main parenchymal cells of origin within the thyroid-the follicular and parafollicular cells [4]. These give rise to; well differentiated thyroid cancer, which includes follicular and papillary subtypes, and poorly differentiated thyroid cancer, which includes anaplastic and medullary subtypes. In terms of histologic presentation of thyroid cancer the majority present with well differentiated subtypes, papillary (80%) and, follicular (10%). Medullary (5-9%) and anaplastic (2%) histologic subtypes present less often. Previous radiation exposure is a risk factor for developing thyroid cancer. 5% of all differentiated thyroid cancers are associated with a familial syndrome and behave clinically more aggressively than sporadic thyroid cancers. These include Gardner syndrome, familial thyroid medullary cancer, familial adenomatous polyposis (FAP), multiple endocrine neoplasia (MEN) and Carney complex [5].

Most patients have an excellent prognosis however a small group of patients experience a more aggressive course that is refractory to treatment. Surgery is adequate treatment for the majority. Up to 90% of patients with thyroid cancer can be considered for treatment with radioactive iodine [6].

There are several novel agents for advanced thyroid cancer under review and future developments will likely include a multimodal, individualized approach based on specific genetic mutations and tumor biology. Here we present on overview of thyroid cancer treatment options.

Papillary Thyroid Cancer

The survival rate for papillary thyroid cancer is over 95% with appropriate treatment and prognosis improves with younger age at diagnosis. It is associated with previous radiation exposure and tends to invade the lymphatic system. Several genetic mutations have been identified in papillary thyroid cancer. Mutations involving RET proto-oncogene (RET/PTC), BRAF or RAS are present in over 70% of papillary thyroid cancers. 5.20% of adults with sporadic papillary tumours have RET/PTC rearrangement. There is fusion of RET/PTC to the 5’ portion of different genes [7]. 45% of those with papillary thyroid cancer carry an activating point mutation of BRAF. This can induce activation of mitogen-activated protein kinase (MAPK) signaling pathways and is associated with more advanced disease at diagnosis and independently predicts for recurrence. Most patients present with a solitary thyroid nodule that is either palpable or found incidentally [8,9]. This can lead to a delay in diagnosis. Most patients have an excellent prognosis however; certain features are associated with a higher risk of recurrence (Table 1).

Treatment for differentiated thyroid cancers involves resection of the primary tumour and radioactive iodine ablation (RAI) which can be repeated several times. RAI can be used for 1) thyroid tissue ablation, 2) high risk for residual disease following surgery and 3) for metastatic disease. Up to 35% will become refractory to RAI. Thyroid hormone replacement is required post-surgery to prevent hypothyroidism, aiming for a TSH between 0.1-0.5 mu/l. TSH suppression has been associated with improved progression free survival (PFS) in patients with papillary thyroid cancer with high risk features [10].

External beam radiation has been used to manage symptomatic local and distant disease. It is indicated for patients with 1) inoperable, residual disease post thyroidectomy 2) resected high risk disease where the likelihood of relapse is high and 3) as a palliative procedure to provide local control for unresectable, symptomatic disease [11,12]. In terms of systemic treatment options chemotherapy has minimal efficacy [13].

In recurrent disease which is localized, surgical resection is favored. If there is widespread involvement, palliative treatment options include; radiiodine ablation, external beam radiation, and local ablative techniques [14]. Palliative surgery for symptom control can also be offered [15].
Familial thyroid cancer is a more aggressive subtype [57,58] and includes distant metastasis, which is associated with increased mortality [61]. Large tumors, older age and dyspnea at presentation [25] are associated with metastatic disease at diagnosis. Respiratory failure is a common feature of anaplastic thyroid cancer, which spreads rapidly and common sites of metastasis include lung, bone and brain. Over 50% of patients present with metastatic disease at diagnosis. Anaplastic thyroid cancer is refractory to EBRT, RAI can be considered, as well as systemic therapies. Post-operative radiation has not been adequately studied and is not appropriate initial treatment option for unresectable or metastatic anaplastic thyroid cancer. A study by Tennvall [26] demonstrated that multimodal treatment in patients with anaplastic thyroid cancer was well tolerated and provided local control. Thirty three patients were treated prospectively with a combination of pre and post-operative hyperfractionated radiotherapy, doxorubicin, and debulking surgery. Complete local remission was obtained in 48% of the patients. Anaplastic thyroid cancer has a poor prognosis with a median survival of one year and accounts for up to 40% of all deaths from thyroid cancer. The aggressive nature of anaplastic thyroid cancer has made clinical therapeutic trials challenging to perform. However, combretastatin A-4 phosphate (CA4P), a novel antiangiogenic vascular targeting agent may have a role to play. A phase I trial in 25 patients with various advanced cancers resulted in one patient with anaplastic thyroid cancer having a complete response [27].

**Medullary Thyroid Carcinoma Overview**

Medullary thyroid cancer is an undifferentiated neuroendocrine tumor of parafollicular cells which produce calcitonin. It makes up 5-9% of all thyroid cancers [2], They are either sporadic (60-70%) [28] or hereditary in origin. Germline mutations in the RET proto-oncogene occur in virtually all patients with hereditary medullary thyroid cancer. All patients should be assessed for presence of MEN syndrome with screening for hyperparathyroidism and phaeochromocytoma. If presence of a familial syndrome is detected, family members should be sent for genetic counseling and consideration of a prophylactic thyroidectomy as the majority will have medullary thyroid cancer or c-cell hyperplasia at surgery [29].

Medullary thyroid cancer commonly presents as a solitary thyroid nodule and in most cases disease has metastasized at diagnosis. Localized disease surgery is the mainstay of treatment as medullary thyroid cancer does not concentrate radiodine. This form of thyroid cancer is relatively chemotherapy resistant [12]. Thyroglobulin suppression is not appropriate for this group as c-cells lack TSH receptors. TSH should be maintained within the normal range [6,7]. Post-operative radiation has not been adequately studied and is not widely used as adjuvant therapy [6,8,9]. Post-op surveillance guidelines recommend two-three weekly carcinoembryonic antigen (CEA) and Calcitonin levels [30]. Patients with raised serum tumor maker levels or symptoms suspicious for recurrence such as palpable neck mass or unresolving respiratory symptoms should have further imaging such as a CT neck, thorax, abdomen, pelvis and a bone scan. Management of symptoms due to excretion of hormonally active peptide may require the use of somatostatin analogues [31]. Common symptoms include Cushing’s syndrome, flushing and diarrhea.

The five year survival rate for medullary thyroid cancer with local nodal involvement is 81% however if there is metastatic disease it decreases to 28% [32]. In sporadic medullary thyroid cancer, somatic mutations of codon 918 has been associated with a poorer prognosis [33,34]. Lack of calcitonin immunostaining, rising CEA levels and postoperative hypercalcitoninemia have all been associated with poorer outcomes [35,36].

<table>
<thead>
<tr>
<th>Patient Factors</th>
<th>Follicular Thyroid Cancer Overview</th>
<th>Medullary Thyroid Carcinoma Overview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at diagnosis</td>
<td>Patients 20-45 years best prognosis [56]</td>
<td>The five year survival rate for medullary thyroid cancer with local nodal involvement is 81% however if there is metastatic disease it decreases to 28% [32]. In sporadic medullary thyroid cancer, somatic mutations of codon 918 has been associated with a poorer prognosis [33,34]. Lack of calcitonin immunostaining, rising CEA levels and postoperative hypercalcitoninemia have all been associated with poorer outcomes [35,36].</td>
</tr>
<tr>
<td>Gender</td>
<td>Men have a more aggressive course [56]</td>
<td></td>
</tr>
</tbody>
</table>
Chemotherapy has a limited role and is not considered first line treatment in patients with metastatic medullary thyroid cancer. There are few long term responses and partial responses range from 10-20% [37]. Most chemotherapeutic regimens combine dacarbazine with 5-fluorouracil, cyclophosphamide, vincristine, streptozocin, or doxorubicin. Combination treatment with cyclophosphamide, vincristine and dacarbazine in one study resulted in 2/7 patients experiencing a durable partial response lasting over a year [38]. Another study reviewed alternating cycles of doxorubicin and streptozocin with 5-fluorouracil and dacarbazine. 15% had partial responses 50% had stable disease for over 8 months [39].

Tyrosine Kinase inhibitors can be considered in a select group of patients who have symptomatic, rapidly growing recurrent or persistent disease. Both Vandetanib and Cabozantinib are oral kinase inhibitors which have demonstrated improved progression free survival (PFS) in metastatic medullary thyroid cancer [40-43]. Vandetanib inhibits RET kinase, vascular endothelial growth factor receptor, and epidermal growth factor receptor signaling. A phase 3 trial of vandetanib versus placebo showed a statistically significant advantage for vandetanib, for PFS. Objective response rate, disease control rate, and biochemical response [44]. Boxed warnings include QT prolongation, torsade de points and sudden death. Of note, vendatanib can decrease calcitonin associated with clinical response in several case reports [50-52]. One case report describes a patient with locally aggressive, treatment resistant medullary thyroid cancer that was unresectable at diagnosis. The patient had no response to chemotherapy but had a dramatic response to sunitinib becoming resectable. The patient underwent thyroideectomy and neck dissection and has no recurrence at follow up (14 months). In a phase II trial of 7 patients with a median follow up of 15.5 months 2 out of 7 patients with progressive refractory medullary thyroid cancer had disease stabilization and 3 out of 7 had a partial response (Table 3) [53-55].

Targeted therapy in combination with radioiodine ablation may represent a novel therapeutic option. The combination of a MEF inhibitor with RIA was used in radioiodine –refractory thyroid cancers with therapeutic benefit. Of the 12 patients who reached the dosimetry threshold for radioiodine therapy, 5 had partial responses and 3 had stable disease. This demonstrated the important potential role of combination treatment in overcoming treatment resistance [56-58].

Pazopanib is a TKI that targets the VEGF receptor that is clinically efficacious in patients with metastatic, rapidly progressive, and radioiodine-refractory differentiated thyroid cancers. A phase 3 study of 37 patients demonstrated a response rate of 49% (95% CI 35-68) lasting longer than 1 year in 66% of patients who responded [59-62].

Toxicities associated with all the VEGF-targeted TKIs include renal impairment, hyper or hypothyroidism, hepatotoxicity, muscle wasting, myelosuppression, thromboembolism, cardiotoxicity, hypertension, and cutaneous toxicity. There is ongoing development of targeted agents including tyrosine kinase, MEK and ALK inhibitors, a PARP-y agonist and combination Dabrafenib and Trametinib therapy [63-65]. Combinations studies targeted agents with systemic therapy there partial response or EBRT are under development. There is also a trial of a vaccine targeting for medullary thyroid cancers targeting CEA producing cells (Table 2).

<table>
<thead>
<tr>
<th>Trial Citation</th>
<th>Phase of Trial</th>
<th>Thyroid cancer subtype</th>
<th>Intervention</th>
<th>Cohort number</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robinson et al. [40]</td>
<td>Phase II</td>
<td>MTC</td>
<td>received 100 mg/d vandetanib</td>
<td>19</td>
<td>ORR 16% (95% CI 3.4-39.6); DCR 68% (95% CI 43.4-87.4)</td>
</tr>
<tr>
<td>Wells et al. [41]</td>
<td>Phase II</td>
<td>MTC</td>
<td>vandetanib 300 mg od</td>
<td>30</td>
<td>20% PR 53% SD ≥ 6 months</td>
</tr>
<tr>
<td>Lam et al. [45]</td>
<td>Phase II</td>
<td>MTC</td>
<td>sorafenib 400 mg bd</td>
<td></td>
<td>PFS 17.9 month</td>
</tr>
<tr>
<td>Kurzrock et al. [63]</td>
<td>Phase I</td>
<td>Advanced solid tumours including 37 with MTC</td>
<td>oral cabozantinib</td>
<td>85</td>
<td>37 had MTC (41%) of 37 patients with MTC had stable disease (SD) for at least ≥ 6 months partial response in 68% of patients with MTC.</td>
</tr>
<tr>
<td>Thornton et al. [64]</td>
<td>Phase III</td>
<td>MTC</td>
<td>vandetanib, 300 mg versus placebo</td>
<td>231 v100</td>
<td>The PFS (hazard ratio = 0.35; 95% confidence interval, 0.24-0.53; P &lt; 0.0001) ORR 44% versus 1%</td>
</tr>
<tr>
<td>Elisei et al. [38]</td>
<td>Phase III</td>
<td>MTC</td>
<td>cabozantinib (140 mg per day) versus placebo</td>
<td>330</td>
<td>PFS 11.2 months for cabozantinib versus 4.0 months for placebo (hazard ratio, 0.28; 95% CI, 0.19 to 0.40; P &lt; .001). RR 28% for cabozantinib and 0% for placebo PFS 14 months, 47.3% for cabozantinib and 7.2% for placebo</td>
</tr>
<tr>
<td>Bible et al. [85]</td>
<td>Phase II</td>
<td>MTC</td>
<td>Pazopanib 800 mg od</td>
<td>35</td>
<td>14% PR (14.3%; 90% confidence interval 5.8%-27.7%) PFS 9.5 months OS 19.9 months</td>
</tr>
</tbody>
</table>

DCR: Disease Control Rate, ORR: Objective Response Rate, SD: Stable Disease, PR: Partial Response, PFS: Progression Free Survival

Table 2: Completed Trials in Medullary Thyroid Cancer.
Phase II of DTC

Table 3: A Selection of Trials currently recruiting in thyroid cancer taken from Clinical Trials.gov.

<table>
<thead>
<tr>
<th>Trial Citation</th>
<th>Phase of Trial</th>
<th>Thyroid Subtype</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety and Efficacy of Sorafenib in Patients With Advanced Thyroid Cancer</td>
<td>Phase II</td>
<td>DTC</td>
<td>Primary: clinical activity and safety profile of sorafenib</td>
</tr>
<tr>
<td>A Study of MLN0128in Metastatic Anaplastic Thyroid Cancer (MTOR kinase)</td>
<td>Phase II</td>
<td>Anaplastic</td>
<td>Secondary: PFS, adverse events a</td>
</tr>
<tr>
<td>Nintedanib (BIBF1120) in Thyroid Cancer (inhibits VEGF,FGF, PDGF receptors)</td>
<td>Phase II</td>
<td>DTC medullary</td>
<td>Primary: PFS</td>
</tr>
<tr>
<td>Dabrafenib With or Without Trametinib in Treating Patients With Recurrent Thyroid cancer</td>
<td>Phase II</td>
<td>Follicular, Insular, Papillary</td>
<td>Primary: ORR</td>
</tr>
<tr>
<td>Study of GI-6207in Patients With Recurrent Medullary Thyroid Cancer(vaccine targeting CEA producing cells)</td>
<td>Phase II</td>
<td>Medullary</td>
<td>Primary: calcitonin growth rate</td>
</tr>
<tr>
<td>Study Comparing Complete Remission After Treatment With Selumetinib /Placebo in Patient With Differentiated Thyroid Cancer(MEK Kinase Inhibitor)</td>
<td>Phase III</td>
<td>DTC</td>
<td>Secondary: CEA-specific T-cells at 3 months, time to progression</td>
</tr>
<tr>
<td>Cabozantinib for the Treatment of Radioiodine -Refractory DTC in the First-line Setting</td>
<td>Phase II</td>
<td>All?</td>
<td>Primary: Overall response, duration of overall response</td>
</tr>
<tr>
<td>Enhancing Radiodine (RAI) Incorporation Into BRAF Mutant, RAI-Refractory Thyroid Cancer with the BRAF Inhibitor Vemurafenib: A Pilot Study</td>
<td>Phase I</td>
<td></td>
<td>Secondary: objective response rate</td>
</tr>
<tr>
<td>Etopateone ( oral PPAR-y agonist) With Paclitaxel Versus Paclitaxel Alone in Treating Patients With Advanced Anaplastic Thyroid Cancer</td>
<td>Phase II</td>
<td>Anaplastic</td>
<td>Primary: os</td>
</tr>
<tr>
<td>Ceritinib (LDK378) in Mutation and Oncogene Directed Therapy in Metastatic or Locally Advanced Anaplastic/Undifferentiated Thyroid Cancer</td>
<td>Phases</td>
<td>Anaplastic</td>
<td>Secondary: RR, PFS, adverse events</td>
</tr>
<tr>
<td>A Study of Two Different Doses of Cabozantinib (XL184) in Progressive, Metastatic Medullary Thyroid Cancer (EXAMINER)</td>
<td>Phase IV</td>
<td>Medullary</td>
<td>Primary: PFS</td>
</tr>
<tr>
<td>Phase II Study of the Optimal Scheme of Administration of Pazopanib in Thyroid Cancer</td>
<td>Phase II</td>
<td>DTC</td>
<td>Secondary: ORR, CR, PR, DCR, PFS, OS, safety profile, QOL</td>
</tr>
</tbody>
</table>

DCR: Disease Control Rate, ORR: Objective Response Rate, SD: Stable Disease, PR: Partial Response, PFS: Progression Free Survival.

Palliative surgery or radiation can be used for symptomatic management of focal disease and bisphosphonate or denosumab can be added for patients with bone involvement.

In advanced rapidly progressive thyroid cancer new agents and multimodality care represent promising therapeutic options for patients. However, these agents are not without risk and clinicians must be judicious with their use, weighing toxicities, quality of life and likely benefits.

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