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An Analysis of the Effectiveness of Carbimazole as an Immunosuppressant for Managing Thyrotoxicosis

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Abstract

This paper investigates the relative effectiveness of two antithyroid drugs, Carbimazole and Propylthiouracil, in treating hyperthyroidism, a common form of thyrotoxicosis. While extensive research has been conducted on the mechanisms of each drug individually, there has been limited comparative research and research addressing patient well-being. Therefore, this study aims to fill this gap by employing both qualitative and quantitative methods, including an extensive literature review and a case study. The results suggest that Carbimazole is the more effective drug, requiring lower dosages and causing fewer side effects. Moreover, Carbimazole is associated with a lower incidence of allergic reactions compared to Propylthiouracil, making it a safer option for the majority of patients. However, patients treated with Propylthiouracil are less likely to relapse. Overall, while Carbimazole is generally considered the safer and more effective treatment for most hyperthyroid patients, the most appropriate treatment depends on individual factors such as age, gender, and medical history.

Introduction

Thyrotoxicosis is characterised by excess thyroid hormone activity, primarily due to elevated levels of thyroid hormones, namely triiodothyronine (T3) and thyroxine (T4), in the bloodstream (Bartalena L, Fatourechi V., 2014). For the purpose of this paper, the focus will be on hyperthyroidism as a form of thyrotoxicosis. Hyperthyroidism is a condition marked by overactivity of the thyroid gland which leads to symptoms such as heart palpitations and increased metabolism. Approximately 70 million people are affected by this condition globally, making it prevalent in certain populations. If left untreated, it can lead to severe complications like heart disease or osteoporosis. Furthermore, hyperthyroidism presents both a severe burden to the healthcare system and a financial strain on the patients themselves. This is because hyperthyroidism, especially when untreated or poorly managed, leads to repeated doctor visits, hospital admissions, and emergency treatments related to the above-mentioned complications. –This makes it highly relevant to medical professionals, patients and the general public, as understanding its symptoms, diagnosis, and treatment can improve health outcomes.

To manage hyperthyroidism and regulate thyroid activity, three main treatment options are available, namely anti-thyroid medications, beta blockers, and radio-iodine therapy (Cleveland Clinic, 2024). Among these, anti-thyroid medications are the most commonly prescribed due to their ability to effectively lower hormone levels. The 2 main drugs that are widely used as anti-thyroid medications are Carbimazole and Propylthiouracil. Carbimazole is particularly significant due to its widespread use, favorable safety profile, and effective long-term control of thyroid hormone levels. Despite both drugs being used

extensively, there is a lack of comprehensive, comparative research on their long-term efficacy and patient well-being outcomes, especially in diverse populations. This study aims to fill that gap, ultimately guiding more effective, individualised treatment choices.

A closer examination of these medications reveals key differences in their chemical composition and mechanisms of action. Carbimazole has a chemical formula of $C_7H_{10}N_2O_2S$. It works to control thyroid activity by making use of metabolic activity. Carbimazole is metabolised to methimazole, and this methimazole is responsible for anti-thyroid activity (PubChem, 2024). On the other hand, Propylthiouracil has a chemical formula of $C_7H_{10}N_2OS$ (PubChem, 2024). Propylthiouracil works by inhibiting the enzyme thyroid peroxidase, which is involved in the synthesis of thyroid hormones (T4 and T3) in the thyroid gland. As can be seen from the above 2 chemical formulae, both molecules only differ by one oxygen atom in their molecular structure, which has significant effects on their medical properties. Comparing Carbimazole to Propylthiouracil is essential to understand their respective efficacy, safety profiles, and long-term outcomes, thereby informing clinical decisions and optimising patient care.

As such, this paper aims to critically evaluate and compare the efficacy and safety profiles of Carbimazole and Propylthiouracil in managing hyperthyroidism. The evaluation and comparison of the 2 drugs will be based on several key criteria: the side effects experienced by patients, the duration of treatment required, and the likelihood of relapses during and after treatment. Secondly, this research paper also aims to evaluate the effectiveness of carbimazole in the treatment of hyperthyroidism through a case study analysis, focusing on the drug's ability to reduce symptoms and prevent long-term complications. Ultimately, this analysis seeks to provide insights into optimising treatment strategies for individuals with hyperthyroidism to enhance patient care.

Literature Review

A comparison of efficacy

Due to the chemical differences between the two molecules, Carbimazole has a longer half-life and more predictable effects as it is metabolized to methimazole. This predictability works in favor of Carbimazole because it reduces the risk of unexpected or untreatable complications, which in turn can enhance patient compliance. With fewer complications or surprises, patients are more likely to stick to their treatment regimens, leading to better management of the condition and improved long-term outcomes. The predictable nature of side effects stems from the fact that once Carbimazole is converted to methimazole, it has a well-understood and consistent mechanism of action in inhibiting thyroid peroxidase, which is involved in the production of thyroid hormones.

A comparison of side effects

There have been many extensive studies that have been conducted about the different side effects of Carbimazole and Propylthiouracil.

Agranulocytosis is the most widely discussed and severe side effect of anti-thyroid medication, and can be caused by either drug. Agranulocytosis is when the neutrophil count in the patient's bloodstream dips below 100 neutrophils per microlitre of blood. This reduction in blood neutrophils makes individuals more prone to infections (National Institutes of Health, 2024). While both anti-thyroid drugs can potentially result in agranulocytosis, it is noteworthy that agranulocytosis is only likely for patients taking carbimazole at higher dosages above 40 milligrams. Most hyperthyroidism patients take carbimazole at lower dosages. Comparing equal dosages of both propylthiouracil and carbimazole, at lower dosages,

which are more commonly taken by patients, propylthiouracil is more likely to cause agranulocytosis. The potential for agranulocytosis in either medication can lead to hospitalization, frequent blood tests, and interruptions in treatment, all of which can significantly impact patient adherence. These disruptions may also negatively affect a patient's quality of life, leading to increased anxiety and stress about the condition. In addition to this serious side effect, both medications have other notable adverse effects.

Other side effects include hepatotoxicity, which is chemical-induced liver damage. Carbimazole hepatotoxicity can result in cholestasis, or the slowing of bile flow from the liver. Cholestasis, while dangerous, is not a primary cause of death. Propylthiouracil hepatotoxicity however, has much more serious effects such as hepatic necrosis, which is fatal and requires liver transplant in most cases (National University Hospital, 2024). The risk of severe hepatotoxicity can lead to increased monitoring and hospitalisations, thus raising the overall healthcare burden for patients. Propylthiouracil is also carcinogenic and has been deemed cancerous by health experts (PubChem, 2024). As such, propylthiouracil is also much more likely to have fatal effects when compared to carbimazole. This carcinogenic risk may also create additional psychological stress for patients, potentially leading to issues with treatment adherence due to fear of long-term health consequences.

Another important factor to consider while determining effectiveness would be the potential for allergies. Research has shown that a significantly smaller population of patients are allergic to carbimazole. About 5 percent of people are allergic to carbimazole while approximately 13 percent of people are allergic to propylthiouracil (Mazhari, Emanuele, & Espiritu, 2020). The higher rate of allergic reactions to propylthiouracil could lead to treatment discontinuation and switching to alternative therapies, which may interrupt the continuity of care and negatively impact treatment adherence. Furthermore, the duration of treatment is much shorter for patients taking carbimazole. Carbimazole controls activity of the thyroid gland much more rapidly compared to Propylthiouracil, and is also required in smaller doses (BTF Thyroid, 2024). The shorter treatment duration associated with carbimazole can significantly improve a patient’s quality of life, as it reduces the long-term burden of daily medication, frequent testing, and possible side effects.

Thus, previous research has shown that the various side effects due to propylthiouracil, such as agranulocytosis, hepatotoxicity and cancer are much more severe. When taking into account that more patients are allergic to propylthiouracil, it seems that carbimazole is a much safer option for patients due to the reduced risk factor and safety concerns.

In certain contexts, the side effects associated with propylthiouracil may be considered less severe than those of carbimazole. One specific example would be the side effects of carbimazole for pregnant women. Carbimazole has been shown to cause teratogenic effects, meaning that it can lead to birth defects in developing fetuses (BTF Thyroid, 2024). This risk makes it an inappropriate choice for pregnant women, particularly during the first trimester. However, it is important to note that the teratogenic risk of carbimazole can be mitigated through the use of alternative medications, such as Propylthiouracil, which is considered safer for use in pregnancy. Carbimazole can cause severe birth defects (BTF Thyroid, 2024) and hence Propylthiouracil would be a better drug for these women to take. It is crucial for clinicians to consider the risks to the fetus when prescribing carbimazole to pregnant women, as the teratogenic effects can lead to lifelong health issues for the child. In addition, propylthiouracil is also more effective in controlling acute cases of hyperthyroidism known as thyroid storm as the chemical properties of propylthiouracil make it the better drug to control such severe conditions. However, pregnant women only make up a small proportion of the patient population and cases of thyroid storm are very rare, meaning

that the effectiveness of carbimazole as an anti-thyroid medication cannot be overlooked just because of certain exceptions.

Hence, by analysis of previously conducted studies, it is logical to conclude that the side effects associated with carbimazole are generally less severe for the general patient demographic. These reduced risks contribute to better overall treatment adherence, quality of life, and more favorable long-term health outcomes for most patients. To verify this generalisation, I have chosen to analyse a case study to corroborate the above-mentioned points.

Case Study: Treatment of Hyperthyroidism with Carbimazole

To further supplement my literature review, through extensive analysis of a case study, I was able to draw more insights regarding the effectiveness of Carbimazole as an anti-thyroid medication. While this case study focuses on a single patient, it offers valuable insight into the real-world application of Carbimazole in managing hyperthyroidism. By analysing the treatment progression and side effects experienced, we can draw relevant comparisons with existing literature on Carbimazole's efficacy and safety profile.

Patient Profile

In this case study, the data provided is from a patient with hyperthyroidism. The patient is a 17-year-old female, and was diagnosed with hyperthyroidism in November 2023. Prior to this diagnosis, the patient did not have any existing medical history. The symptoms experienced by the patient include severe weight loss, and extreme hunger. In fact, the patient would feel hungry even immediately after consuming a meal. Furthermore, the patient would experience tunnel vision and light-headedness.

Treatment Plan

Hyperthyroidism is often assessed through the measurement of thyroid-stimulating hormone receptor antibodies (TSH receptor antibodies) because these antibodies can stimulate the thyroid gland, leading to increased hormone production. Patient's TSH receptor antibodies were 27.40 H before medication was prescribed. Taking into account these symptoms and hormone levels, the patient was prescribed carbimazole to help manage T3 and T4 levels. The choice of carbimazole was due to the fact that the degree of hyperthyroidism in this patient was not very severe. The proposed duration of treatment was 18 months, until June 2025 and the initial dosage administered was 30 mg every morning. Patient was to be regularly monitored and reviewed through blood checks conducted in 2 month intervals. After the blood checks, the dosage of carbimazole would be adjusted depending on levels of T3 and T4 in the bloodstream.

Results

In the first 2 months, the patient was adjusting very well to the medication and did not experience any side effects. The carbimazole was also effective in regulating T3 and T4 levels. TSH Receptor Antibodies in the bloodstream reduced from 27.40 H to 19.2 H. Afterwhich, the dosage was reduced from 30mg to 10mg for the next interval. Unfortunately, the decreased dosage was not as effective and the patient suffered from a relapse. TSH Receptor Antibodies in the bloodstream shot up**.** There was subsequently an increase in dosage from 10mg to 15mg, which was slightly more effective in regulating thyroid activity. This was followed by a reduction to 10mg, and after further reduction in TSH Receptor Antibodies, dosage was decreased to 7.5mg. Patient is currently taking 7.5 mg every morning.

The table below is a summary of the data for levels of T3 and T4 in patients' bloodstream for different dosages of carbimazole.

Month	Dosage of Carbimazole Taken daily	TSH Receptor Antibodies in Bloodstream*
Nov 2023	30 mg	27.40 H
Jan 2024	10 mg	19.20 H
Mar 2024	15 mg	13.70 H
May 2024	20 mg	16.50 H
Jul 2024	10 mg	8.2 H
Sep 2024	7.5 mg	10.0 H

Table 1 * Acceptable range for TSH Receptor Antibodies is 8.8 H to 14.4 H

Findings

As can be observed from the above data in Table 1, there was a great reduction in the levels of TSH in patients bloodstream in the first 4 months (Nov 2023 to Mar 2024). However, relapse number 1 occurred from Mar 2024 to May 2024, where levels of TSH increased. While the increase in TSH levels suggests a possible decrease in carbimazole's effectiveness, it is important to consider other factors that might have contributed to this relapse. Factors such as the patient's diet, potential interactions with other medications, or lifestyle choices, including stress or inconsistent adherence to the medication regimen, could have played a role. As the dosage increased, the levels of TSH decreased in the subsequent months. It is important to note that dosage was too high in July 2024, and the levels of TSH decreased below acceptable range. TSH levels were too low and thus needed to be increased again. Hormone levels were brought back under control by increasing dosage. Dosage was finally decreased to 7.5mg.

The following is an anecdote from the patient about how she felt taking the medication. She mentioned that after the first 2 months, she felt a lot better, and even like "a whole new person". Furthermore, she stated that the effects of the medication kicked in quite rapidly and that she did not experience any side effects. This improvement in the patient's subjective experience aligns with the clinical data, which showed a reduction in TSH receptor antibodies from 27.40 H to 19.20 H after the first two months (Table 1). Her hyperthyroidism symptoms were also mitigated, as she started gaining weight and felt hungry less often. These subjective improvements correspond with the reduction in TSH receptor antibodies, suggesting that the medication was effective in reducing thyroid activity and metabolism. This illustrates that the medication has been effective in reducing thyroid activity and metabolism.

The above case study is a great demonstration of the effectiveness and rapidity of Carbimazole in controlling thyroid activity. Furthermore, the case study corroborates existing literature. A certain research paper has highlighted the fact that it takes as little as 2 months for a hyperthyroid patient to feel better, and the patient above stated that she felt the effects of the medicine significantly about 2 months into the treatment.

While the case study sheds light on the positives of taking Carbimazole as an anti-thyroid medication, such as rapidity of action and smaller chance of side effects, it also illustrates one important detriment that cannot be overlooked. This would be the frequency of relapses. The patient in question relapsed twice in the span of 10 months. Since dosages were evaluated in 2 month intervals, patient relapsed for 2 out of 5 follow-ups, which is a significant percentage.

However, when the negatives of taking Carbimazole are weighed against the negatives of taking Propylthiouracil, the severity of side effects for Propylthiouracil are far more dangerous and duration of treatment of Propylthiouracil is longer. This is as opposed to the greater frequency of relapses for a patient taking Carbimazole. Overall, since Carbimazole is able to effectively contain the activity of the thyroid hormone with fewer side effects, it is the more effective anti-thyroid medication when compared with propylthiouracil. Even though a patient taking carbimazole typically has a longer period of treatment and a higher chance of relapse, carbimazole still outweighs propylthiouracil in-terms of general patient comfort and well-being.

To address the concern of a greater frequency of relapses, it would be good to improve on the treatment. However, the frequency of relapses does depend on the individual patient's immune system, and the relative adaptability of their thyroid glands. Hence, there is not much that can be done to reduce the risk of relapse.

Discussion

In this discussion section, I would like to discuss 2 main sub points regarding my research, namely limitations and ethical concerns.

Limitations

Firstly, it is important to consider the limitations that come with using existing research. There are inconsistencies with the data used in previous studies, and certain data seem to contradict each other. Furthermore, the studies analysed used relatively small sample sizes, and thus the data may not be representative of the larger hyperthyroidism patient population. In addition, the studies I have used to validate my points have been conducted by researchers of various countries. The effect of geographical location on one's physical well-being cannot be overlooked. Geographical location plays a crucial role in determining access to healthcare, environmental factors, diet, and lifestyle, all of which can significantly impact physical health. Since geographical locations vary, it is important to consider how these variations may contribute to differences in health outcomes. It is not fair to corroborate these data points by comparing them with one another without accounting for the unique regional factors that may influence the findings. For instance, individuals living in urban areas may have better access to healthcare facilities and healthier food options compared to those in rural or remote regions, which could lead to discrepancies in the results. Thus, the geographical context of each data point must be considered to understand how it may affect the overall conclusions of the study. Lastly, certain studies that were referenced are quite outdated, and the data may not be as relevant in today's day and age where significant advancements to healthcare have been made.

There also exist significant limitations in the case study that I have used as the focal point of this paper. The data is quite limited in scope due to the fact that it only looks at one patient, and this data cannot be used to generalise a broader range of patients. The focus on a single patient severely compromises the external validity of the study, as the results cannot be reliably extrapolated to the general population of

hyperthyroid patients. Furthermore, the lack of diversity in the case study sample means that responses to Carbimazole may not reflect how the drug works in a more varied population, including individuals with different ages, comorbidities, or lifestyle factors. Additionally, the patient in question has not completed the full 18 months of treatment, so it is not possible to tell exactly how effective the medication will be in the long term. Late-onset side effects are also not accurately captured in this case study. Due to the small nature of this case study, it was not conducted in a controlled manner. As such, different variables such as the patient's lifestyle, diet, and co-existing health conditions could have affected the frequency of relapses as well as the overall effectiveness of the medication. Given these factors, it is difficult to make definitive claims about the drug's effectiveness across a broader range of individuals. Furthermore, potential biases in the selection of the case study may also influence the findings, as the patient's specific characteristics may not be representative of the larger population of hyperthyroid patients.

Thus, to improve on this, such variables should be controlled in future studies to ensure consistency and accuracy of data. Furthermore, in order to consider the long term effectiveness and late-onset side effects, longer follow up studies are required. To ensure objectivity, it would have been more ideal to consider a similar case study on a patient undergoing treatment with propylthiouracil, but unfortunately, I was unable to source such a study for this paper due to the limited resources at hand. Overall, more extensive and controlled case studies are needed to establish broader, more general conclusions.

Ethical Concerns

As with all research that involved human subjects, there have been many ethical considerations that have gone into this paper, especially regarding the case study. The case study that I have used in this paper includes data that I had obtained from a relative with hyperthyroidism. The first ethical concern that I would like to discuss would be informed consent. I had told this relative about my research paper and mentioned that the data that they provide would be analysed completely objectively, and it would be a completely anonymous process. Hence, they were also informed of the risks of providing their data for my paper.

A further critical aspect of informed consent is ensuring that the participant understands their right to withdraw at any time without consequence. It is extremely critical to maintain patient confidentiality as well as make sure that they are informed of the potential risk factors when participating in such studies. This boils down to the key principles of research and ensures that patient well-being is not violated.In this case, it was crucial to ensure that any personal data or identifiable health information was kept confidential, thus preventing any unauthorised access to sensitive material.

The next ethical concern that I would like to address is a more broad one that is more related to the topic of anti-thyroid medications as a form of treatment. Both Carbimazole and Propylthiouracil are prescription medications, and patients would need to be prescribed these medications by a general practitioner. Propylthiouracil is associated with significant risks, such as liver toxicity, which can be life-threatening in some cases. Therefore, healthcare providers must fully inform patients about these potential risks and ensure that they understand the implications of taking such medications. Additionally, some anti-thyroid medications, like Carbimazole, may not be suitable for certain populations, such as pregnant women, due to the risks they pose to both the mother and the fetus.

As such, healthcare providers have the responsibility to weigh the benefits of treatment against potential risks and side effects, ensuring that patient welfare is prioritised.

Conclusion

In conclusion, this paper has shown that Carbimazole seems to be the more effective drug for a broader range of patients who are affected by hyperthyroidism as opposed to Propylthiouracil through an extensive literature review as well as a case study. However, it is important to acknowledge that one patient is insufficient to draw broad, generalising conclusions meaning that my research is a starting point rather than a definitive study. Further research with larger sample sizes are necessary to validate the above findings. Only with more robust studies can the relative efficacy of these drugs be fully understood and confidently applied in clinical practice.

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