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Original Research Article

Detection of TSPY Gene in Turner Syndrome and Its Variants

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Abstract

Background: Detecting hidden Y mosaicism in patients with Turner syndrome is a primary goal of molecular testing because it significantly increases the risk of gonadoblastoma. Studies have shown in monosomy 45, X patients diagnosed through standard karyotyping were revealed to have hidden Y material by multiplex PCR. TSPY (Testis Specific Protein Y-linked) is located in the proximal region of the short arm of the chromosome Y, an oncogenic region. Normally, it functions in male germ cell proliferation, but behaves as a proto-oncogene when ectopically expressed in dysgenetic gonads.

Objective: To detect hidden Y chromosome sequences using the TSPY gene in patients with Turner syndrome.

Methods: PCR Amplification of TSPY gene was conducted using a forward primer of 5'-CATCCAGAGCGTCCCTGGCTT-3' and a reverse primer of 5'-CCCCACACACATGCACTTACC-3.' The PCR thermal cycle followed initial denaturation at 95^0C for 5 min, 35 cycles of denaturation at 94^0C for 1 min, annealing at 55^0C for 45 s, extension at 72^0C for 1 min, and final extension at 72^0C for 5 min. Gel electrophoresis was performed in 1% agarose gel and interpreted under computerized illumination with UV light.

Results: There were 22 Turner syndrome patients diagnosed clinically and confirmed using conventional karyotyping. PCR analysis did not detect the hidden Y chromosome of the TSPY gene in 13 (59%) patients with 45 X and mosaic X karyotypes. Meanwhile, the TSPY gene was amplified in nine (41%) patients with mosaic 46,XY.

Conclusion: Molecular detection of hidden Y chromosomes in patients with TS is significant in facilitating diagnosis and management, especially in laboratories that lack cytogenetic capabilities. Identification of the TSPY gene is crucial, as it plays an important role in predisposing host cells to tumorigenesis and the development of gonadoblastoma. Counselling and deliberative decision-making are fundamental to analyzing laboratory findings, clinical features, and patient quality of life.

Keywords: *TSPY gene; Turner syndrome; PCR*
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INTRODUCTION

Turner syndrome (TS) is a chromosomal abnormality present in 1:2000 live-born females.[1] The phenotype is variable, including short stature, gonadal dysgenesis, typical appearance, low posterior hairline, and lymphedema. In 50-60% of cases, the karyotype reveals a monosomy of X chromosome (45,X), while the other exhibit structural abnormalities of other form as deletion, isochromosome X, ring chromosome and mosaicism variants 45,X/46XX, 45,X/46XY, or

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45,X/47XX, meanwhile between 6% to 11% of patients possess Y chromosome material.[2–4] Of the patients who appeared to have a "pure" 45,X karyotype through standard karyotyping were revealed to have hidden Y material by the multiplex Polymerase Chain Reaction (PCR).[5,6]

Standard karyotyping may fail to identify low-frequency cell lines, especially those involving the Y chromosome.[7,8] Molecular analysis has become an essential method for assessing Y chromosome fragments.[9,10] PCR can identify 30.9% (17 of 55) of patients carrying Y chromosome sequences. Ten of these patients had been classified as Y-negative by classic karyotyping but were found to be Y-positive through molecular testing.[11] Bianco et al. utilized PCR to screen for hidden Y chromosome material and were able to detect Y-chromosome sequences in 16.3% (17 out of 104) of the TS patients. The SRY (Sex-determining Region Y) gene was detected in all 17 of these patients, while the TSPY (Testis-Specific Protein Y-linked) gene was found in 4 of them (3.8%).[12] Molecular studies to search for specific sequences such as SRY and TSPY genes is needed because it is more sensitive for detecting cryptic mosaicism.[10,13]

Detecting hidden Y mosaicism is a primary goal of molecular testing in TS because the presence of Y material significantly increases the risk of gonadal tumors, namely gonadoblastoma, with an estimated incidence of 11% to 20%.[13] Gonadoblastoma is a benign tumor with a high potential for malignancy. In approximately 60% of cases, it can differentiate into invasive dysgerminoma.[14,15]

TSPY is considered a critical marker because it is the primary candidate for the Gonadoblastoma on the Y (GBY) locus, which is the only known oncogenic region on the human Y chromosome. TSPY is located in the proximal region of the short arm of the Y chromosome (Yp11.1), which has been identified as the susceptibility region for gonadoblastoma.[14] While TSPY normally functions in male germ cell proliferation, it behaves as a proto-oncogene when ectopically expressed in dysgenetic gonads. Because the presence of the entire Y chromosome is the main risk factor, an early prophylactic gonadectomy is often recommended to avoid these malignancies.[14,16]

Despite the clinical importance of detecting Y-chromosome material in Turner syndrome, data from Indonesian patients remain limited. Therefore, this study aimed to detect the TSPY gene using PCR and evaluate its usefulness as a molecular marker.

MATERIALS AND METHODS

This was a cross–sectional descriptive study with a purposive sampling method. This study was conducted at the Center for Biomedical Research (CEBIOR), Faculty of Medicine, Diponegoro University, Semarang, and the KK Women and Children Hospital Laboratory, Singapore. The inclusion criteria were patients diagnosed with TS clinically and confirmed using conventional karyotyping. Patients who agreed to participate were asked to fill out Informed Consent.

Amplification of the TSPY gene by PCR was performed using the forward primer 5'-CATCCAGAGCGTCCCTGGCTT-3' and reverse primer 5'-CCCCACACACATGCACTTACC-3.' PCR reaction flow in a total volume of 50 µl, including extracted DNA, 20pmol of each forward and reverse primer, and 25 µl of Master Mix (containing 2.5 units of Taq DNA polymerase, 1x PCR buffer with 1.5 mM $MgCl_2$, and 200 µM each dNTP (Qiagen, Hilden, Germany). The PCR thermal cycle was as follows initial denaturation at 95^0C for 5 min, 35 cycles of denaturation at 94^0C for 1-minute, annealing at 55^0C for 45 s, extension at 72^0C for 1 min, and final extension at 72^0C for 5 min. Gel electrophoresis was performed in a 1% agarose gel running at 120V for 30 min, in the PCR machine AB Biosystem, Verriti 96 well, and interpreted under computerized illumination UV light.

To increase the specificity and sensitivity of the PCR reaction, an internal control using the FGFR2 gene was added. Since this gene is in the autosomal genome on chromosome 10, amplification of both TSPY and FGFR2 genes enhances the positive finding of PCR. Normal male and female DNA samples were used as positive and negative controls, respectively. Data collection was performed by examining the presence of the TSPY gene, which was demonstrated through gel electrophoresis with a PCR product size of 780 bp. Ethical clearance was granted by the Health Research Ethics Committee of Diponegoro University and Dr. Kariadi Central General Hospital Semarang prior to the implementation of the research. (Reference number: 149/EC/FK/RSDK/2011).

RESULTS

Between 2004 and 2011, 22 patients with TS were treated at the Center for Biomedical Research (CEBIOR), Semarang. Eight (61.54%) patients revealed 45, X monosomy karyotype. Five samples showed 45,X/46, XX in 15.38% of the samples and 45, X/46, X,i(X)(q10) in 23.08% of the samples. The remaining nine samples showed Y chromosome material in their genomes. The karyotype results are presented in Table 1.

Table 1. Karyotype result

No.	Karyotype	N (%)
1.	45,X	8 (36.0%)
2.	45,X[12]/46,XX[13]	2 (9.0%)
3.	45,X/46,X,i(X)(q10)	3 (14%)
4.	46,X,r(Y)/45,X	1(5%)
5.	mos 45,X[13]/46,XY[17]	7 (32%)
6.	45,X/46,XX/46,XY	1 (5%)
	Total	22 (100%)

The TSPY gene was tested in control samples, which consisted of two normal females and two normal males. (see Figure 1).

Figure 2 shows that PCR of the TSPY gene was performed in all samples of TS. In non-Y chromosome, there was no amplification of the TSPY gene. All samples containing Y chromosome material were positive for TSPY. The TSPY gene was amplified

in the normal male control. The internal control, FGFR2, was amplified in all samples except the blank.

In sample of patients with TS who had a Y chromosome in their genome, the TSPY gene was amplified using PCR. The FGFR2 gene was also successfully amplified, indicating that the PCR specificity was maintained (Figure 3).

The summary results of the PCR amplification for the TSPY gene in TS patients are listed in Table 2. Thirteen (59%) patients showed no amplification of the TSPY gene, and the remaining nine (41%) showed TSPY gene amplification. This result is in accordance with their karyotype features, which contain or do not contain Y chromosome material in their genome.

DISCUSSION

Routine chromosome testing (karyotyping) is often insufficient, as it only detects Y chromosome material in approximately 6% of patients with TS. However, more sensitive molecular techniques like Polymerase Chain Reaction (PCR) and Fluorescence In Situ Hybridization (FISH) have revealed a much higher prevalence, identifying "hidden" Y material in up to 60% of patients.[17] In this study, TSPY gene was not detected in 13 patients with monosomy 45, X or mosaic X. However, 9 (41%) of the samples were positively

Table 2. Result of the amplification of TSPY gene in turner syndrome patients

Karyotyping	Amplification of *TSPY* gene	
	Negative	Positive
mos 45, X[13]/46,XY[17]		ü
mos 45,X[13]/46,XY[17]		ü
46,X,r(Y)/45,X		ü
45,X/46,XX	ü	
45,X/46,X,i(X)(q10)	ü	
mos 45, X[13]/46,XY[17]		ü
mos 45,X[13]/46,XY[17]		ü
45,X/46,XX	ü	
45,X	ü	
45,X/46,XX/46,XY		ü
45,X/46,X,i(X)(q10)	ü	
mos 45, X[13]/46,XY[17]		ü
mos 45,X[13]/46,XY[17]		ü
45,X	ü	
45,X	ü	
45,X	ü	
45,X	ü	
mos 45,X[13]/46,XY[17]		ü
45,X/46,X,i(X)(q10)	ü	
45,X	ü	
45,X	ü	
45,X	ü	
Total	13	9
(%)	59%	41%

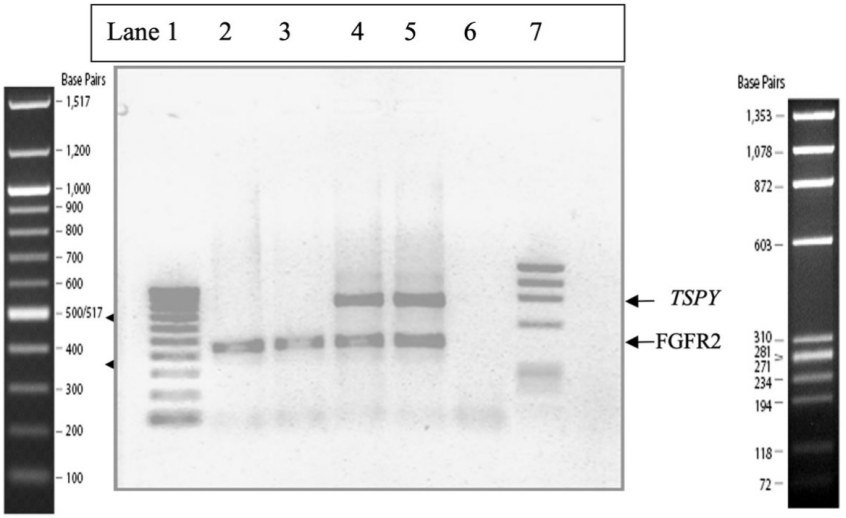

Figure 1. Amplification of TSPY and FGFR2 primers on normal female and male control
Lane 1.PCR marker 100bp; lanes 2 and 3. Normal female control; lanes 4 and 5. Normal male control; lane 6. Blank; lane 7.PCR marker Φx 174. PCR product of *TSPY* gene as 780bp, while FGFR2 gene as 440bp

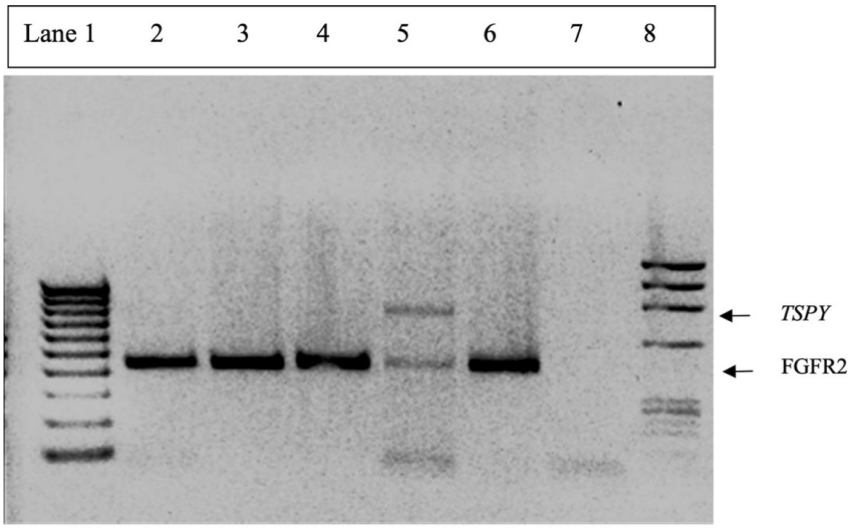

Figure 2. Amplification of TSPY and FGFR2 primers on Turner patients with no Y chromosome constituents Lane 1.PCR marker 100bp; lanes 2 and 3. sample monosomy X; lane 4 sample mosaic X; lane 5. normal male control; lane 6. normal female control; lane 7. Blank; lane 8.PCR marker Φx 174. PCR product of *TSPY* gene as 780bp, while FGFR2 gene as 440bp

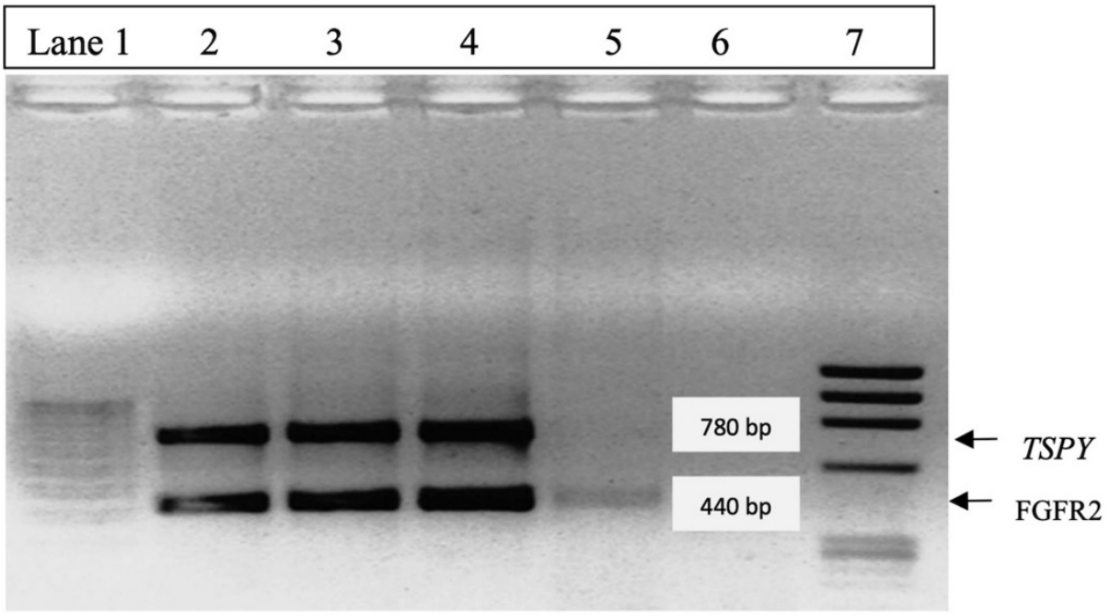

Figure 3. Amplification of TSPY and FGFR2 primers on Turner patients with Y chromosome constituents Lane 1.PCR marker 100bp; lanes 2 and 3. sample mosaic Y; lane 4. normal male control; lane 5. normal female control; lane 6. Blank; lane 7.PCR marker Φx 174. PCR product of *TSPY* gene as 780bp, while FGFR2 gene as 440bp

amplified the TSPY gene in mosaic patients with Y chromosome in karyotyping analysis. PCR is the preferred technique for the initial tracking of various Y-chromosome sequences because it is inexpensive, sensitive, and rapid. PCR is considered more accurate and reliable than traditional karyotyping, as it does not require cell culture, is capable of detecting low-level mosaicism, has the ability to process multiple samples simultaneously, and can be performed using a very small amount of material.[18] In contrast, FISH is often used in association with PCR to confirm the presence and location of Y chromosome material. [19]

Molecular studies have increased the sensitivity of cryptic Y-chromosome detection by amplifying Y-specific sequences. Barbosa et al. compared two different types of tissue for DNA extraction such as peripheral blood lymphocytes (mesoderm origin) and oral mucosal cells (ectoderm origin) using multiplex PCR specifically targeted the SRY and TSPY gene, is able to identified Y markers in 12.8% of the patients, many of whom had been previously diagnosed with a non-mosaic (45,X) karyotype.[20] In other study by Soares, et.al found that 58% (18 out of 31) of the TS participants had chromosome mosaicisms. Mosaicisms can be tissue-specific, meaning they might be present in oral cells even if they are not detected in blood lymphocytes. Traditional karyotyping may be insufficient, and

additional testing in different tissues is necessary to accurately define a patient's chromosomal makeup and long-term health risks. [21]

The risk of developing gonadoblastoma is nearly identical in both the overt Y-chromosome group (Y material easily identified through conventional cytogenetics) and the cryptic Y-chromosome group ("hidden" material and can only be detected using more sensitive molecular methods like PCR) (in 16.7% vs 20.0%, respectively).[22] Silveri, et.al found out of 84 patients with TS, six were identified as high-risk based on the presence of the TSPY and SRY gene (detected via PCR) and evidence of "streak" gonads via ultrasonography. Pathological examination revealed gonadoblastoma (100%) and dysgerminoma. They suggest early prophylactic gonadectomy as the treatment of choice when Y-chromosome material is present in bilateral streak gonads.[23]

Detecting "cryptic" Y-material in patients with Turner syndrome is not just about identifying the karyotype but also understanding the DNA damage mechanism and the patient's long-term prognosis. Analyzing the expression of associated genes (OCT4, SRY, and TSPY) is crucial because it can reveal modifications in the gonadal microenvironment that predispose patients to cancer before a tumor actually forms. [12] In the study by Cardano, if cells contain Y-material, such as the SRY gene, it could block the tumor-suppressive function of the X-linked gene TSPYL2 (TSPX), which provides a protective mechanism to stop the growth of damaged cells.[24] TSPX (TSPY homologue on X-chromosome) normally acts as a tumor suppressor by retarding the cell cycle. When TSPY is present in a female environment, it counteracts the inhibitory functions of TSPX, disrupting normal cell cycle checkpoints and leading to genomic instability.[15,22,25]

The TSPY gene family is clinically significant because of its role in male fertility and its potential as an oncogene. It plays a vital role in the proliferation and differentiation of male stem germ cells (spermatogonia and gonocytes). Furthermore, TSPY expression is dosage-dependent, meaning the amount of protein produced is directly related to the number of gene copies present, thus deletions or structural rearrangements are linked to clinical phenotypes like infertility and azoospermia.[26] Ectopic expression of TSPY led to a significant increase (30–45%) in cell proliferation and if expressed in the dysgenetic gonads of phenotypic females or dysfunctional testes, it acts as an oncogene.[27]

The presence of TSPY in the dysgenetic gonads of individuals with Turner syndrome predisposes host cells to tumorigenesis and the development of gonadoblastoma. TSPY interacts with type B cyclins and enhances CDK1 kinase activity, accelerating the transition from the G2 to the M phase of the cell cycle, leading to rapid cell division. Overexpressing TSPY leads to the up-regulation of various progrowth genes and oncogenes, including those on chromosome 12p that are frequently amplified in testicular germ cell tumors.[15,27] The complete sequence provide more accurately measure TSPY dosage to study its correlation with fertility and cancer, differentiate between intact protein-coding genes and pseudogenes, provide more precise genetic counselling for individuals with Y-chromosome variations.[26]

Updated guidelines suggest a more individualized approach that respects patient autonomy, weighing the risk of malignancy against the potential benefits of maintained gonadal function, such as spontaneous puberty or rare spontaneous pregnancies.[16] Current clinical practice guidelines also recommend prophylactic gonadectomy at the time of diagnosis in Turner Syndrome who possess Y-chromosome material. However, malignant transformation typically does not occur until the second decade of life. The study suggests individualized decision-making rather than an immediate surgical mandate at diagnosis. This approach allows for the possibility of spontaneous puberty (occurring in 42% of the study participants) and provides time for patients and families to weigh the benefits of endogenous hormone production and future fertility potential against the risk of malignancy. [13,28]

This study demonstrated the significant use of PCR to identify and confirm the existence of Y chromosome segments in patients with TS. However, only one gene was analyzed in a limited number of patients. Further studies with additional variants and Y–specific sequences are needed to gain a more extensive understanding of the presence of the hidden Y chromosome and its clinical role mechanism. In addition, the clinical features of patients should be monitored for the development of virilization, which must be considered in the management of patients with dysgenetic gonads.

CONCLUSION

Molecular detection of hidden Y chromosomes in patients with Turner Syndrome is significant in facilitating diagnosis and management, especially in laboratories that lack cytogenetic capabilities. PCR offers a sensitive and specific approach that is rapid and able to analyze multiple samples simultaneously. Identification of TSPY gene is crucial as it plays an important role in predisposes the host cells to tumorigenesis and the development of gonadoblastoma. Further studies with multiple markers, different tissue samples, and clinical cohort follow-up are needed to gain comprehensive management. Although positive detection requires a gonadectomy, counselling and deliberative decision-making are fundamental to analyze laboratory findings, clinical features, and patient quality of life

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REFERENCES

1. Stochholm K, Juul S, Juel K, Naeraa RW, Gravholt CH. Prevalence, incidence, diagnostic delay, and mortality in Turner syndrome. Journal of Clinical Endocrinology and Metabolism.

2006;91(10):3897–902. DOI:10.1210/jc.2006-0558 PubMed PMID: 16849410.
2. Li X. Sex chromosomes and sex chromosome abnormalities. Clinics in Laboratory Medicine. 2011. p. 463–79. DOI:10.1016/j.cll.2011.08.013 PubMed PMID: 22118732.
3. Gürsoy S, Erçal D. Turner Syndrome and Its Variants. The Journal of Pediatric Research. 2017 Dec 19;171–5. DOI:10.4274/jpr.35744
4. Sybert VP, Mccauley E. Turner's Syndrome. n engl j med. 2004;12:351. DOI:10.1056/NEJMra030360
5. Akcan AB, Boduroğlu OK. Y Chromosome Material in Turner Syndrome. Cureus. 2021 Nov 29. DOI:10.7759/cureus.19977
6. Lene Garcia B, Maria Anunciação S, Adriana Aparecida SM, Magnus Régius D da S, Angela Maria SC. Y Chromosome Sequences in Turner Syndrome: Multiplex PCR, a New Method for Diagnosis. J Genet Genome Res. 2020 Dec 31;7(1). DOI:10.23937/2378-3648/1410052
7. Ackermann A, Bamba V. Current controversies in turner syndrome: Genetic testing, assisted reproduction, and cardiovascular risks. Journal of Clinical and Translational Endocrinology. Elsevier; 2014. p. 61–5. DOI:10.1016/j.jcte.2014.05.003
8. Wolff DJ, Van Dyke DL, Powell CM. Laboratory guideline for turner syndrome. Genetics in Medicine. Nature Publishing Group; 2010. p. 52–5. DOI:10.1097/GIM.0b013e3181c684b2 PubMed PMID: 20081420.
9. Bianco B, Lipay MV, Melaragno MI, Guedes AD VIT. Detection of hidden Y mosaicism in Turner's syndrome: importance in the prevention of gonadoblastoma. J Pediatr Endocrinol Metab. 2006;19(9):1113–7.
10. Nur Semerci C, Lale Satiroglu-tufan N, Turan S, Bereket A, Tuysuz B, Yilmaz E, et al. Detection of Y Chromosomal Material in Patients with a 45,X Karyotype by PCR Method. Tohoku J Exp Med. 2007;243(3):243–9. DOI:10.1620/tjem.211.243
11. Rojek A, Obara-Moszynska M, Kolesinska Z, Rabska-Pietrzak B, Niedziela M. Molecular detection and incidence of Y chromosomal material in patients with turner syndrome. Sexual Development. 2018 Feb 1;11(5–6):254–61. DOI:10.1159/000484880 PubMed PMID: 29248931.
12. Bianco B, Oliveira KC, Guedes AD, Barbosa CP, Lipay MVN, Verreschi ITN. OCT4 gonadal gene expression related to the presence of Y-chromosome sequences in Turner syndrome. Fertil Steril. 2010 Nov;94(6):2347–9. DOI:10.1016/j.fertnstert.2010.02.036 PubMed PMID: 20347080.
13. Gravholt CH, Andersen NH, Christin-Maitre S, Davis SM, Duijnhouwer A, Gawlik A, et al. Clinical practice guidelines for the care of girls and women with Turner syndrome Proceedings from the 2023 Aarhus International Turner Syndrome Meeting. In: European Journal of Endocrinology. Oxford University Press; 2024. p. G53–151. DOI:10.1093/ejendo/lvae050 PubMed PMID: 38748847.
14. Ibarra-Ramírez M, Campos-Acevedo LD, Martínez de Villarreal LE. Chromosomal Abnormalities of Interest in Turner Syndrome: An Update. J Pediatr Genet. 2023 Dec;12(04):263–72. DOI:10.1055/s-0043-1770982
15. Lau YFC, Li Y, Kido T. Gonadoblastoma locus and the TSPY gene on the human y chromosome. Birth Defects Research Part C - Embryo Today: Reviews. 2009. p. 114–22. DOI:10.1002/bdrc.20144 PubMed PMID: 19306348.
16. Turner HE, Johannsen EB, Smyth A, Orchard E, Gravholt CH. Approach to the Patient With Turner Syndrome. Journal of Clinical Endocrinology and Metabolism. Endocrine Society; 2026. p. 268–79. DOI:10.1210/clinem/dgaf517 PubMed PMID: 40971503.
17. Shen W, Li Y. Gonadoblastoma in Turner syndrome with puberty delay: A case report and literature review. Molecular Genetics and Genomic Medicine. John Wiley and Sons Inc; 2023. DOI:10.1002/mgg3.2300 PubMed PMID: 37822273.
18. Da Silva-Grecco RL, Trovó-Marqui AB, de Sousa TA, Da Croce L, Balarin MAS. Identification of Y-Chromosome Sequences in Turner Syndrome. Indian J Pediatr. 2016 May 1;83(5):405–9. DOI:10.1007/s12098-015-1929-6 PubMed PMID: 26634260.
19. De Marqui ABT, Da Silva-Grecco RL, Balarin MAS. Prevalence of Y-chromosome sequences and gonadoblastoma in Turner syndrome. Revista Paulista de Pediatria. Sao Paulo Pediatric Society; 2016. p. 114–21. DOI:10.1016/j.rppede.2015.12.004 PubMed PMID: 26525685.
20. Barbosa LG, Siviero-Miachon AA, Souza MA, Spinola-Castro AM. Recognition of the Y chromosome in Turner syndrome using peripheral blood or oral mucosa tissue. Ann Pediatr Endocrinol Metab. 2021 Dec 1;26(4):272–7. DOI:10.6065/apem.2142026.013
21. Soares JS, da Silva Lago RMR, Toralles MBP, Mota LR, Alves ES, de Carvalho AFL. Searching chromosome mosaicisms in 45,X Turner syndrome: how relevant is it? Arch Endocrinol Metab. 2021;65(6):739–46. DOI:10.20945/2359-3997000000403 PubMed PMID: 34762780.
22. Kwon A, Hyun SE, Jung MK, Chae HW, Lee WJ, Kim TH, et al. Risk of Gonadoblastoma Development in Patients with Turner Syndrome with Cryptic Y Chromosome Material. Horm Cancer. 2017 Jun 1;8(3):166–73. DOI:10.1007/s12672-017-0291-8 PubMed PMID: 28349385.
23. Silveri M, Grossi A, Bassani F, Orazi C, Camassei FD, Zaccara A. Ullrich-Turner Syndrome and Tumor Risk: Is There Another Chance to Early Gonadectomy in Positive TSPY and SRY Patients? European Journal of Pediatric Surgery. 2016 Jun 1;26(3):273–6. DOI:10.1055/s-0035-1551568 PubMed PMID: 25978024.
24. Cardano M, Magni M, Alfieri R, Chan SY, Sabbioneda S, Buscemi G, et al. Sex specific regulation of TSPY-Like 2 in the DNA damage

response of cancer cells. Cell Death Dis. 2023 Mar 1;14(3). DOI:10.1038/s41419-023-05722-2 PubMed PMID: 36918555.

25. Vogt PH, Besikoglu B, Bettendorf M, Frank-Herrmann P, Zimmer J, Bender U, et al. Gonadoblastoma y locus genes expressed in germ cells of individuals with dysgenetic gonads and a y chromosome in their karyotypes include DDX3Y and TSPY. Human Reproduction. 2019 Apr 1;34(4):770–9. DOI:10.1093/humrep/dez004 PubMed PMID: 30753444.
26. Rhie A, Nurk S, Cechova M, Hoyt SJ, Taylor DJ, Altemose N, et al. The complete sequence of a human Y chromosome. Nature. 2023 Sep 14;621(7978):344–54. DOI:10.1038/s41586-023-06457-y PubMed PMID: 37612512.
27. Oram SW, Liu XX, Lee TL, Chan WY, Lau YFC. TSPY potentiates cell proliferation and tumorigenesis by promoting cell cycle progression in HeLa and NIH3T3 cells. BMC Cancer. 2006 Jun 9;6. DOI:10.1186/1471-2407-6-154 PubMed PMID: 16762081.
28. Dabrowski E, Johnson EK, Patel V, Hsu YC, Davis S, Goetsch AL, et al. Turner Syndrome with Y Chromosome: Spontaneous Thelarche, Menarche, and Risk of Malignancy. J Pediatr Adolesc Gynecol. 2020 Feb 1;33(1):10–4. DOI:10.1016/j.jpag.2019.08.011 PubMed PMID: 31465855.