I. Introduction

Wolf-Hirschhorn syndrome is a well-described contiguous gene deletion syndrome that causes severe global developmental delays, seizures, growth retardation, microcephaly, and distinct craniofacial features described as a "Greek warrior helmet" appearance. Early chromosome studies identified a number of terminal 4p deletions with heterogeneous breakpoints in individuals diagnosed with Wolf-Hirschhorn syndrome. Initial genotype-phenotype correlation studies utilizing both fluorescence in situ hybridization (FISH) and microarray analyses refined the terminal 4p deletions to a minimal ~1.9 Mb critical region. However, questions still remained as to what genes were responsible for the individual phenotypes associated with Wolf-Hirschhorn syndrome.

To further refine the critical region, additional studies compared smaller overlapping deletions within the 1.9 Mb terminal 4p deletion. This analysis resulted in the characterization of the Wolf-Hirschhorn critical region (WHSCR). However, variable expressivity of phenotypes associated with deletions that included the WHSCR prompted researchers to re-examine the region ultimately leading to refinement to the WHSCR-2. The WHSCR-2 encompasses two genes: NSD2 and LETM1. NSD2 was initially thought to contribute to the abnormal facial features as well as the global developmental delay, while LETM1 has been implicated in seizure development. However, recent studies have suggested that deletions involving NSD2 and LETM1 may only contribute to a subset of the features of Wolf-Hirschhorn syndrome including growth deficiency, feeding difficulties, and speech and motor delays, suggesting that deletion of additional genes is required for full expression of the phenotype.

We present a case that further highlights the difficulty in establishing a minimal critical region for expression of phenotypes related to Wolf-Hirschhorn syndrome.

II. Materials and Methods

We received amniotic fluid and a maternal peripheral blood sample from a 39 year old female referred at 20 weeks gestation for prenatal microarray analysis. Paternal peripheral blood and buccal cells as well as peripheral blood from the paternal grandparents were also received for follow-up analyses. DNA purification was performed using a Maxell® 16 Mb Research Instrument (Promega®). Blood and amniotic fluid, and samples were purified using a Maxell® 16 Blood DNA Purification Kit. Buccal samples were purified using a Maxell® 16 Buccal Swab LEV DNA Purification Kit.

Microarray analysis was performed using the Affymetrix® CytoScan HD array [Affymetrix® and CytoScan® are Registered Trademarks of Affymetrix, Inc.]. This array contains approximately 2.695 million markers across the entire human genome. There are approximately 743,000 SNPs and 1,953,000 structural variations. The genome contains approximately 2.695 million markers across the entire human genome. There are approximately 743,000 SNPs and 1,953,000 structural variations.

qPCR analysis was performed using the QuantStudio™ 7 Flex Real-Time PCR system (Applied Biosystems®) in conjunction with the VeriQuest™ SYBR Green qPCR Master Mix (Applied Biosystems®) with ROX (2X) (2000 rxn). All samples were run in triplicate using primers (FWD: GTGAAAACAGGAGTGAGTGGTCG, REV: AGCTGACTGCTGACATCTTC) specific to an amplicon within the FGRF3 locus, rs466131,1797,193-1,797,302, in conjunction with normal controls (one female and one male from Promega®, and one male from Applied Biosystems®). Copy number ratio for specific CNVs were made as follows: qPCR value of 0=0 copies, from .06 to 1.4=1 copy, from 1.4 to 2.5=2 copies, from 2.5 to 3.4=3 copies and 3.6 to 4.4=4 copies.

III. Results

Proband: Microarray analysis was performed on DNA isolated from cultured amniocytes from a 39 year old female referred for testing at 20 weeks gestation due to multiple ultrasound abnormalities including renal hypoplasia and growth deficiency. Microarray analysis revealed a 748 kb interstitial deletion of 4p16.3 that includes 13 OMIM genes and spans the entire WHSCR-2 region (Figure 1). The deletion was confirmed by qPCR analysis using a deletion specific amplicon targeting the FGRF3 locus (Figure 2A).

Maternal: Follow-up qPCR analysis of peripheral blood from the 39 year old female showed two copies of the FGRF3 localized amplicon, ruling out a maternal carrier of the deletion (Figure 2B).

Paternal: Clinical evaluation at 40 years old revealed no apparent congenital anomalies and an above average intelligence. Contrary to what was expected, the paternal peripheral blood sample was positive for deletion of the FGRF3 locus by qPCR analysis (Figure 2C). Deletion of the entire 748 kb region was confirmed by microarray analysis of the same peripheral blood sample (Figure 3). The deletion appeared to be present in 100% of cells in both the follow-up qPCR and microarray analyses. DNA was isolated from paternal buccal cells and assayed by microarray (Figure 4). The deletion appears to be present in 100% of buccal cells reducing the likelihood of tissue specific mosaicism.

Paternal grandparents: To determine the inheritance of the 748 kb deletion in the paternal carrier, qPCR analyses were performed on the paternal grandparents. Both grandparents showed two copies of the FGRF3 localized amplicon suggesting the deletion occurred de novo in the paternal carrier (Figure 5).

IV. Conclusions

The initial 748 kb deletion of 4p16.3 found by microarray analysis of cultured amniocytes, combined with the reported ultrasound abnormalities, is highly suggestive of a prenatal diagnosis of Wolf-Hirschhorn syndrome. However, the deletion was found to be inherited from a clinically normal paternal carrier. These results indicate that although the deletion may have contributed to the phenotypic abnormalities in the fetus, it was not sufficient in the paternal carrier to lead to the expression of phenotypes associated with Wolf-Hirschhorn syndrome or the subset of features found in individuals with smaller WHSCR-2 deletions.

Previously described individuals with smaller overlapping 4p16.3 deletions that include the WHSCR-2 region present with abnormal phenotypic characteristics including growth deficiency, feeding difficulties, and motor and speech delays. However, these individuals lack seizures and the typical craniofacial findings associated with Wolf-Hirschhorn syndrome. All previously characterized overlapping deletions that include the WHSCR-2, in cases where parental analysis was available, have been found to be de novo. The paternal carrier presented here is the first unaffected individual reported to carry a deletion that spans the WHSCR-2 critical region. One explanation as to why the paternal carrier is unaffected is that deletion of the WHSCR-2 region is associated with a greater degree of variable expressivity than what has been reported previously, further implicating the involvement of additional genes in the penetrance of the disorder. A second explanation is that given the deletion occurred de novo, the paternal carrier is a tissue specific mosaic. Although, no mosaicism was observed in either the peripheral blood or buccal analysis, the possibility that the paternal carrier is a tissue specific mosaic. Although, no mosaicism was observed in either the peripheral blood or buccal analysis, the possibility that the paternal carrier is a tissue specific mosaic. Although, no mosaicism was observed in either the peripheral blood or buccal analysis, the possibility that the paternal carrier is a tissue specific mosaic. Although, no mosaicism was observed in either the peripheral blood or buccal analysis, the possibility that the paternal carrier is a tissue specific mosaic. Although, no mosaicism was observed in either the peripheral blood or buccal analysis, the possibility that the paternal carrier is a tissue specific mosaic. Although, no mosaicism was observed in either the peripheral blood or buccal analysis, the possibility that the paternal carrier is a tissue specific mosaic.